
AIRPLANE UPSET RECOVERY
Industry Solutions for Large Swept-Wing Turbofan Airplanes Typically Seating More Than 100 Passengers
Briefing

Figure 3-B.1

Accidents resulting from a loss of airplane control have been, and continue to be, a major contributor to fatalities in the worldwide commercial aviation industry. National Transportation Safety Board (NTSB) data show that between 1994 and 2003, there were at least 32 worldwide airline accidents attributed to airplane upset. There were more than 2100 fatalities as a result of these upsets and subsequent accidents.


Figure 3-B.2

Upsets have been attributed to environment, equipment, and pilot factors. The data also suggest that pilots need to be better prepared to cope with airplane upsets. Research by operators has indicated that most airline pilots rarely experience airplane upsets, and many have never been trained in maximum performance maneuvers.

# Causes of Airplane Upset

Figure 3-B.3

Airplane upsets that are caused by environmental factors are difficult to predict; therefore, training programs stress avoidance of such phenomena. Complete avoidance is not possible, as the statistics suggest; therefore, the logical conclusion is that pilots should be trained to safely recover an airplane that has been upset.

# Airplane Upset Recovery

Figure 3-B.4

The goal of an Upset Recovery Training Program is twofold:

- To increase the pilot’s ability to recognize and avoid upset situations.
- To improve the pilot’s ability to recover control, if avoidance is not successful.

# Upset Recovery Training Objectives

- To increase the pilot’s ability to recognize and avoid upset situations.
- To improve the pilot’s ability to recover control, if avoidance is not successful.

Figure 3-B.5

This briefing, as part of the overall Upset Recovery Training Program, is presented in three parts:

- The causes of airplane upsets.
- A brief review of swept-wing airplane fundamentals.
- Airplane upset recovery techniques.

# Upset Recovery Training Will Review

- The causes of airplane upsets
- Swept-wing airplane fundamentals
- Airplane upset recovery techniques

Figure 3-B.6

For discussion purposes, the following *unintentional* conditions generally describe an airplane upset:

- Pitch attitude greater than 25 deg nose up.
- Pitch attitude greater than 10 deg nose down.
- Bank angle greater than 45 deg.
- Within the above parameters, but flying at airspeeds inappropriate for the conditions.

A pilot must not wait until the airplane is in a fully developed and defineable upset before taking corrective action to return to stabilized flight path parameters.

The amount and rate of control input to counter a developing upset must be proportional to the amount and rate of pitch, roll, and/or yaw experienced.

# What is “Airplane Upset?”

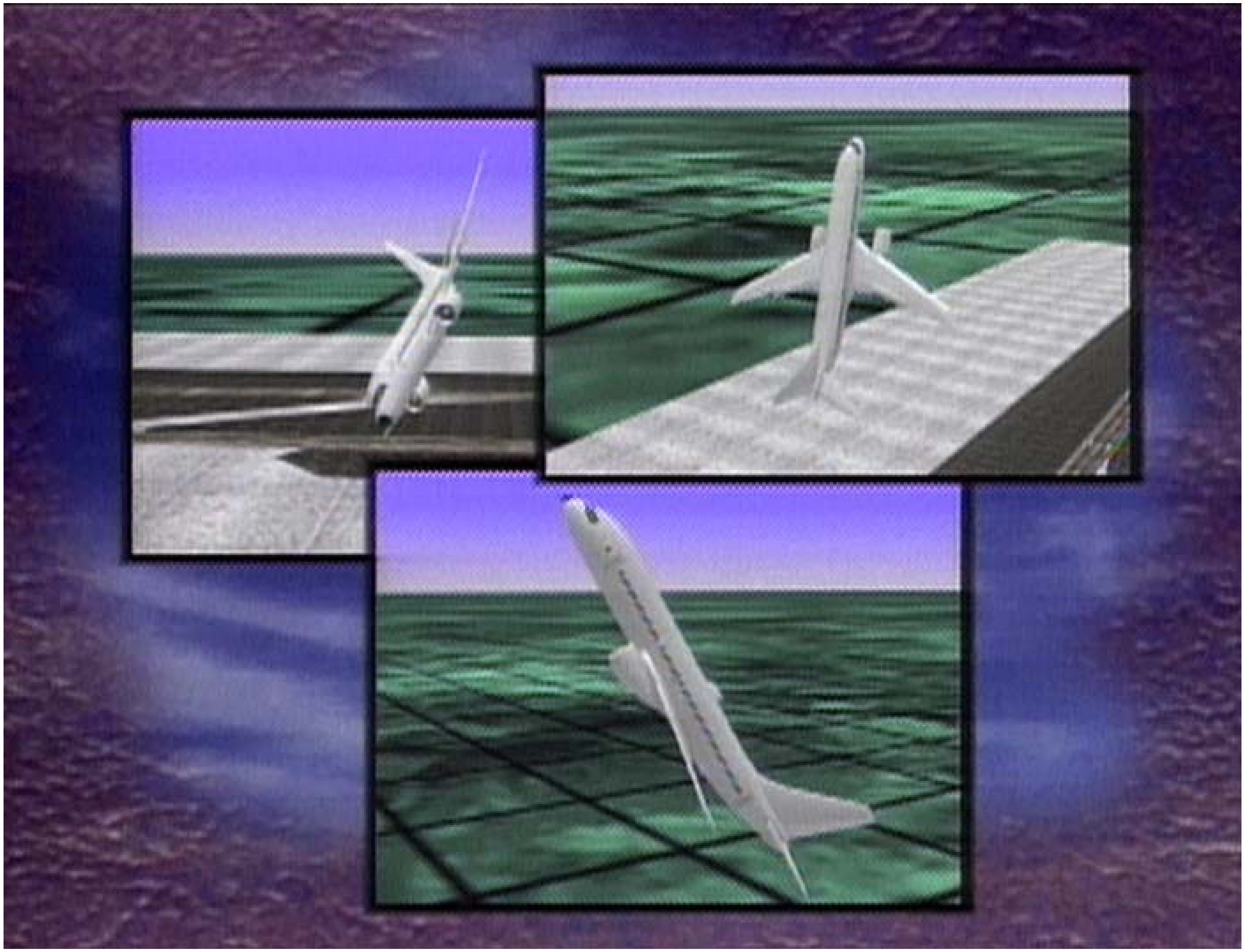


Figure 3-B.7

# Causes of Airplane Upset Incidents Are Varied

The causes of airplane upset incidents are varied; however, they can be broken down into four broad categories. They can be

- Environmentally induced.
- Systems-anomalies induced.
- Pilot induced.
- A combination of causes.

# Causes of Airplane Upset Incidents Are

- Environmentally induced
- Systems-anomalies induced
- Pilot induced
- A combination of all three

Figure 3-B.8

# Environmentally Induced Airplane Upsets Include

- Turbulence.
- Clear air turbulence.
- Mountain wave.
- Windshear.
- Thunderstorms.
- Microbursts.
- Wake turbulence.
- Airplane icing.

# Environmental Causes of Airplane Upset Include

- Turbulence
- Clear air turbulence
- Mountain wave
- Windshear
- Thunderstorms
- Microbursts
- Wake turbulence
- Airplane icing

Figure 3-B.9

# Turbulence

Turbulence is characterized by a large variation in an air current over a short distance. It is mainly caused by

- Jet streams.
- Convective currents.
- Obstructions to wind flow.
- Windshear.

Knowledge of the various types of turbulence assists in avoiding it and, therefore, the potential for an airplane upset.

# Turbulence Is Primarily Caused by

- Jet streams
- Convective currents
- Obstructions to wind flow
- Windshear

Figure 3-B.10

# Clear Air Turbulence (CAT)

Clear air turbulence (CAT) is defined as "high-level turbulence," as it is normally above 15,000 MSL. It is not associated with cumuliform cloudiness, including thunderstorms. CAT is almost always present near jet streams. Jet streams are dynamic, and turbulence associated with them is difficult to predict. The area of turbulence can be 100 to 300 mi long—50 to 100 mi wide—and 2000 to 5000 ft thick.

# Clear Air Turbulence (CAT) Is Characterized by Marked Changes in

- Pressure
- Temperature
- Wind direction
- Wind velocity

Figure 3-B.11

# Mountain Wave Turbulence

Mountains are the greatest obstructions to wind flow. Therefore, this type of turbulence is classified as “mechanical.” Rotor or lenticular clouds over mountains are a sure sign of Mountain Wave Turbulence, but unfortunately the air may be too dry for the presence of the telltale clouds. Severe turbulence can be expected in mountainous areas, if the perpendicular wind component exceeds 50 kn.

# Mountain Wave Turbulence

Figure 3-B.12

# Windshear

Wind variations at low altitude are recognized as a serious hazard to airplanes during takeoff and approach. These variations can be caused by many differing meteorological conditions:

- Topographical.
- Temperature inversions.
- Sea breezes.
- Frontal systems.
- Strong surface winds.
- Thunderstorms.
- Microbursts.

The latter two, thunderstorms and microbursts, are the two most violent forms of wind change, and they will be discussed in more detail.

# Windshear

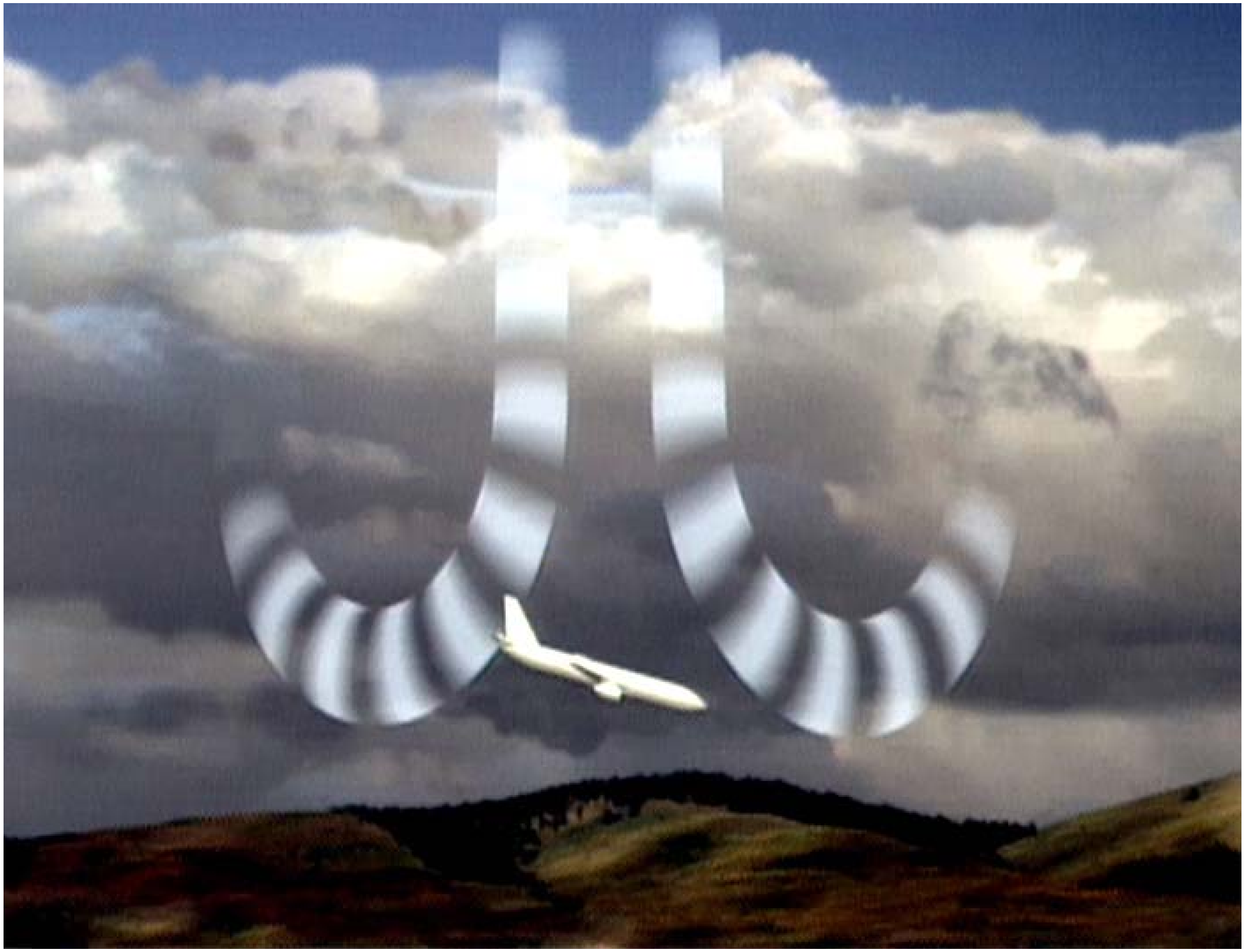


Figure 3-B.13

# Thunderstorms

There are two basic types of thunderstorms: airmass and frontal.

Airmass thunderstorms are randomly distributed in unstable air. Heated air rises to form cumulus clouds. The clouds develop in three stages: cumulus stage, mature stage, dissipating stage. The gust front produced by the downflow and outrush of rain-cooled air can produce very turbulent air conditions.

Frontal thunderstorms are associated with weather system line fronts, converging wind, and troughs aloft. Frontal thunderstorms form in squall lines; last several hours; generate heavy rain, and possibly hail; and produce strong gusty winds, and possibly tornadoes. The downdraft of a typical frontal thunderstorm is large, about 1 to 5 miles in diameter. Resultant outflows may produce large changes in windspeed.

# Thunderstorms

Figure 3-B.14

# Microbursts

Microbursts can occur anywhere convective weather conditions occur. Five percent of all thunderstorms produce microbursts. Downdrafts are typically only a few hundred to 3000 ft across. The outflows are not always symmetrical. A significant airspeed increase may not occur upon entering outflows, or it may be much less than the subsequent airspeed loss experienced when exiting. ***It is vital to recognize that some microbursts cannot be successfully escaped with any known techniques.***

# Microbursts

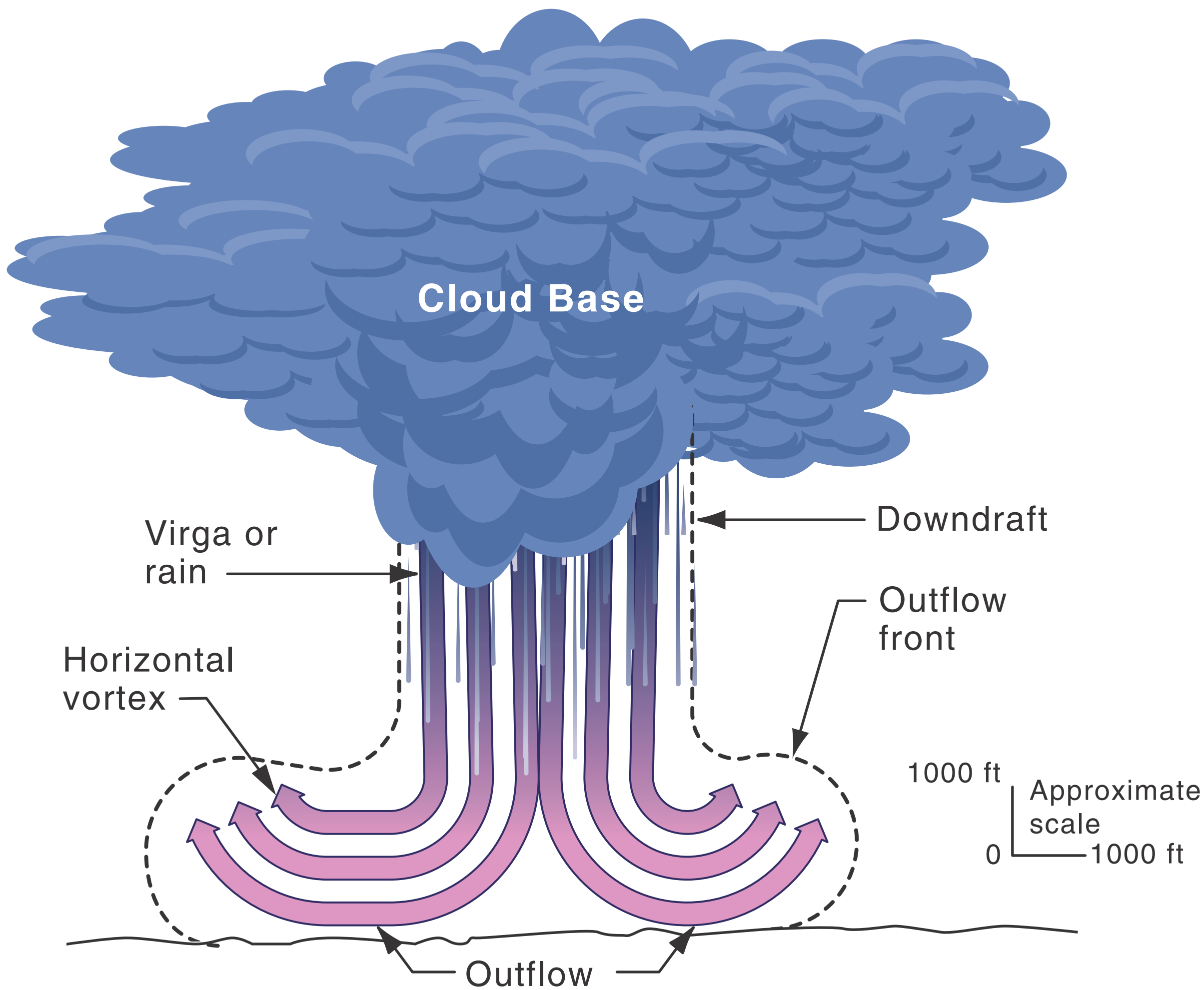



Figure 3-B.15

# Wake Turbulence

Wake turbulence is the leading cause of airplane upsets that are environmentally induced. A pair of counter-rotating vortices is shed from an airplane wing, thus causing turbulence in the airplane's wake. The strength of the turbulence is a function of airplane weight, wingspan, and speed. Vortices descend at an initial rate of 300 to 500 ft/min for about 30 sec. The descent rate decreases and eventually approaches zero at 500 to 900 ft below the flight path. Avoidance can be accomplished by flying above the offender's flight path. Maintaining a vertical separation of at least 1000 ft below the flight path is also considered safe. Pilots have likened a wake-turbulence encounter to be like "hitting a wall." Counter-control is usually effective. With little to no control input from the pilot, the airplane would be expelled from the wake and an airplane upset could result.

# Wake Turbulence

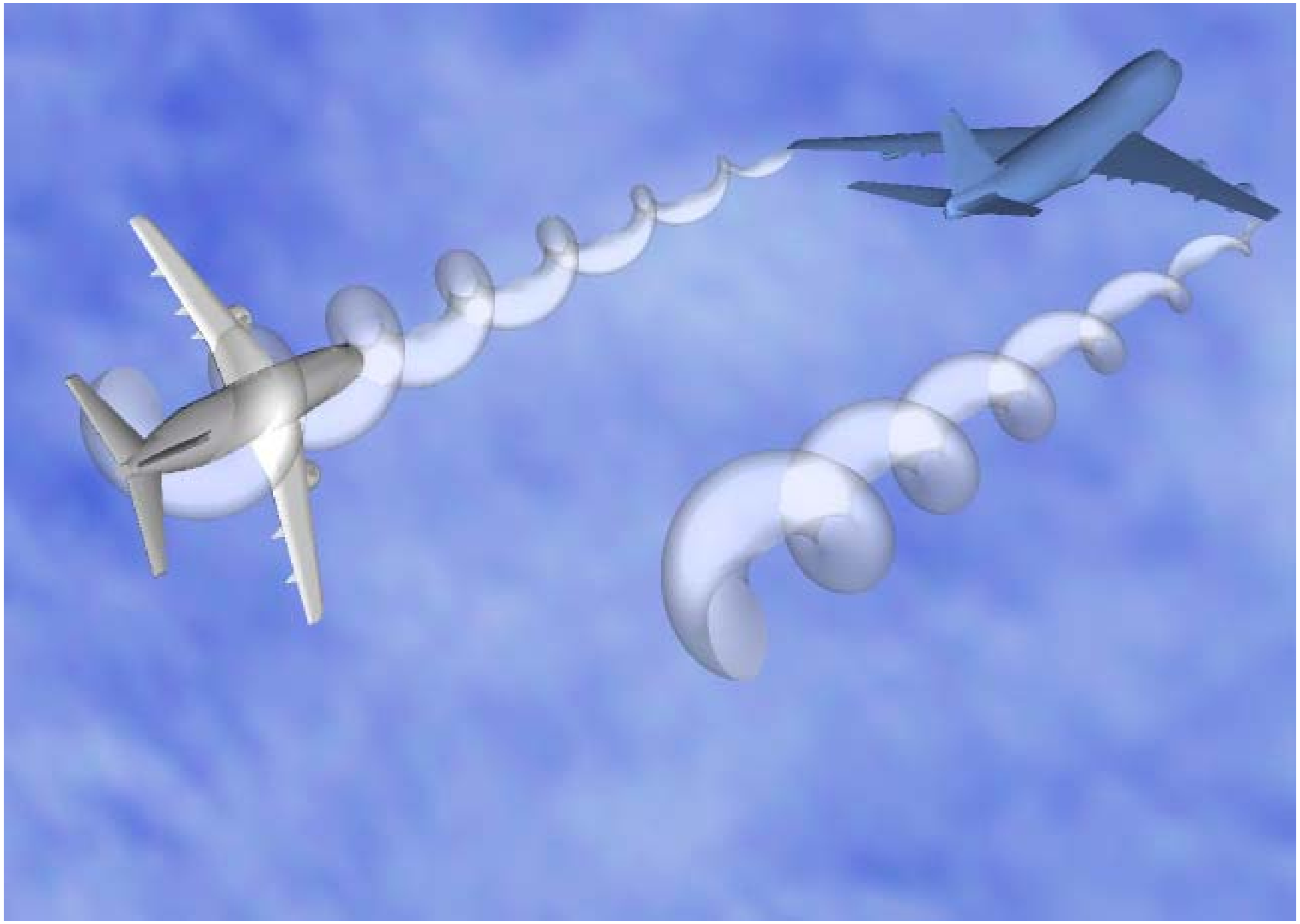


Figure 3-B.16

# Airplane Icing

Large degradation of airplane performance can result from the surface roughness of an extremely small amount of ice contamination. The handling characteristics and maximum lift capability can be adversely affected. Unanticipated changes in stability and control are very real possibilities. Therefore, the axiom of "keep it clean" for critical airplane surfaces continues to be a universal requirement.

This concludes our discussion of environmental elements that may lead to an airplane upset. The next subject for discussion involves airplane upsets that are induced by systems anomalies.

# Airplane Icing

Figure 3-B.17

# Systems-Anomalies Induced Airplane Upsets

The discussion will include

- Flight instruments.
- Autoflight systems.
- Flight controls and other anomalies.

# System-Anomalies Induced Airplane Upsets Primarily Involve

- Flight instruments
- Autoflight systems
- Flight controls and other anomalies

Figure 3-B.18

# Systems-Anomalies Induced Airplane Upsets

In spite of improved airplane design, intensified training programs, and improved reliability, we still experience systems failures. Some of these failures can lead to an airplane upset. Most failures are survivable if the flight crew makes correct responses.

# System-Anomalies Induced Airplane Upsets


Figure 3-B.19

# Flight Instruments

Instrument failures are infrequent, but they do occur. All airplane operations manuals provide flight instrument system information, such that when instrument failures do occur, the pilot can analyze the impact and select the correct procedural alternatives. Airplane certification requires that pilots have the minimum information needed to safely control the airplane in the event of instrument failure. Several accidents point out that pilots are not always prepared to correctly analyze the alternatives in case of failure. The result is an airplane upset.

# Flight Instruments


Figure 3-B.20

# Autoflight Systems

Autoflight systems include autopilot, autothrottles, and all related systems that perform flight management and guidance. The systems integrate information from a variety of other aircraft systems. The pilot community has tended to develop a great deal of confidence in the systems, which has led to complacency in some cases. Although quite reliable, failures do occur. These failures have led to airplane upsets and accidents.

# Autoflight Systems


Figure 3-B.21

# Flight Control and Other Anomalies

Flap asymmetry, spoiler problems, and other flight control anomalies are addressed in airplane operations manuals. Airplane certification requirements ensure that pilots have sufficient information and are trained to handle these critical failures. However, it is the unexpected that can cause problems, particularly during critical phases of flight.

# Flight Control and Other Anomalies


Figure 3-B.22

# Pilot-Induced Airplane Upsets

We have known for many years that sensory inputs can be misleading to pilots, especially when pilots cannot see the horizon. To solve this problem, airplanes are equipped with flight instruments to provide the necessary information for controlling the airplane. Subjects for discussion in this area include

- Instrument cross-check.
- Inattention and distraction from primary cockpit duties.
- Vertigo or spatial disorientation.
- Improper use of airplane automation.

# Pilot-Induced Causes of Airplane Upset Include

- Instrument misinterpretation or slow cross-check
- Inattention and distraction from primary cockpit duties
- Vertigo or spatial disorientation
- Improper use of airplane automation

Figure 3-B.23

# Instrument Cross-Check

Instrument misinterpretation or a slow cross-check can lead to an airplane upset. Many minor upsets can be traced to an improper instrument cross-check. However, a good cross-check and proper interpretation is only one part of the equation. It is necessary for the pilot to make the correct adjustments to pitch, bank, and power in order to control the airplane.

# Instrument Cross-Check


Figure 3-B.24

# Inattention or Distraction From Primary Cockpit Duties

A review of airplane upsets reveals that inattention or neglecting to monitor the airplane's performance can lead to extreme deviations from the normal flight envelope. Neglecting to monitor all the instruments or fixating on a certain instrument can lead to performance deviations. Distractions can be very subtle, such as warning or caution lights illuminating during critical phases of flight. Many airplane upsets occur while the pilot is engaged in some task that takes attention away from the flight instruments. "Control the airplane first" should always be the guiding principle.

# Distraction

Figure 3-B.25

# Vertigo or Spatial Disorientation

Spatial disorientation has been a significant factor in many airplane-upset accidents. The definition of spatial disorientation is the inability to correctly orient oneself with respect to the Earth’s surface. We are all susceptible to sensory illusions. Pilots who perceive a conflict between bodily senses and the flight instruments and are unable to resolve the conflict are spatially disorientated. Allowed to continue, spatial disorientation will lead to airplane upset. Attention to flight instruments and a good cross-check are the keys to remaining spatially orientated.

# Vertigo or Spatial Disorientation


Figure 3-B.26

# Improper Use of Airplane Automation

The advancement of technology in today's modern airplanes has brought us flight directors, autopilots, autothrottles, and flight management systems. When used properly, this technology contributes to flight safety and reduces crew workload. Complacent and improper use of these systems is a concern. The systems can and do fail, leading to airplane upsets and accidents.

# Improper Use of Airplane Automation

Figure 3-B.27

# Causes of Airplane Upsets—Summary

Three basic causes

1. Environmentally induced:

- Turbulence, CAT, mountain wave, windshear, thunderstorms, microbursts, wake turbulence, and airplane icing.

2. Systems-anomalies induced:

- Flight instruments, autoflight systems, and flight control anomalies.

3. Pilot induced:

- Instrument cross-check, inattention and distraction from primary cockpit duties, vertigo or spatial disorientation, and improper use of airplane automation.

The next part of this briefing will focus on basic airplane fundamentals as they apply to us as pilots of swept-wing transport airplanes.

# Causes of Airplane Upsets—Summary

1. Environmental:

    Turbulence, CAT, mountain wave, windshear, thunderstorms, microbursts, wake turbulence, and airplane icing

2. Systems anomalies:

    Flight instruments, autoflight systems, and flight control anomalies

3. Pilot induced:

    Instrument cross-check, inattention and distraction from primary cockpit duties, vertigo or spatial disorientation, and improper use of airplane automation

Figure 3-B.28

# Swept-Wing Airplane Fundamentals for Pilots

The areas of interest include

- Flight dynamics.
- Energy states.
- Load factors.
- Aerodynamic flight envelope.
- Aerodynamics.

# Swept-Wing Airplane Fundamentals Will Overview

- Flight dynamics
- Energy states
- Load factors
- Aerodynamic flight envelope
- Aerodynamics

Figure 3-B.29

# Flight Dynamics

In understanding the flight dynamics of large, swept-wing transport airplanes, it is important to first understand what causes the forces and moments acting on the airplane and then move to what kinds of motion these forces cause. With this background, we can gain an understanding of how a pilot can control these forces and moments in order to direct the flight path.

Newton's first law states that an object at rest will tend to stay at rest, and an object in motion will tend to stay in motion in a straight line, unless acted on by an external force. If an airplane in motion is to deviate from a straight line, there must be a force, or a combination of forces, imposed to achieve the desired trajectory. The generation of the forces is the subject of aerodynamics (to be discussed later). The generation of forces requires energy, which for discussion purposes can be called "energy state."

# Flight Dynamics

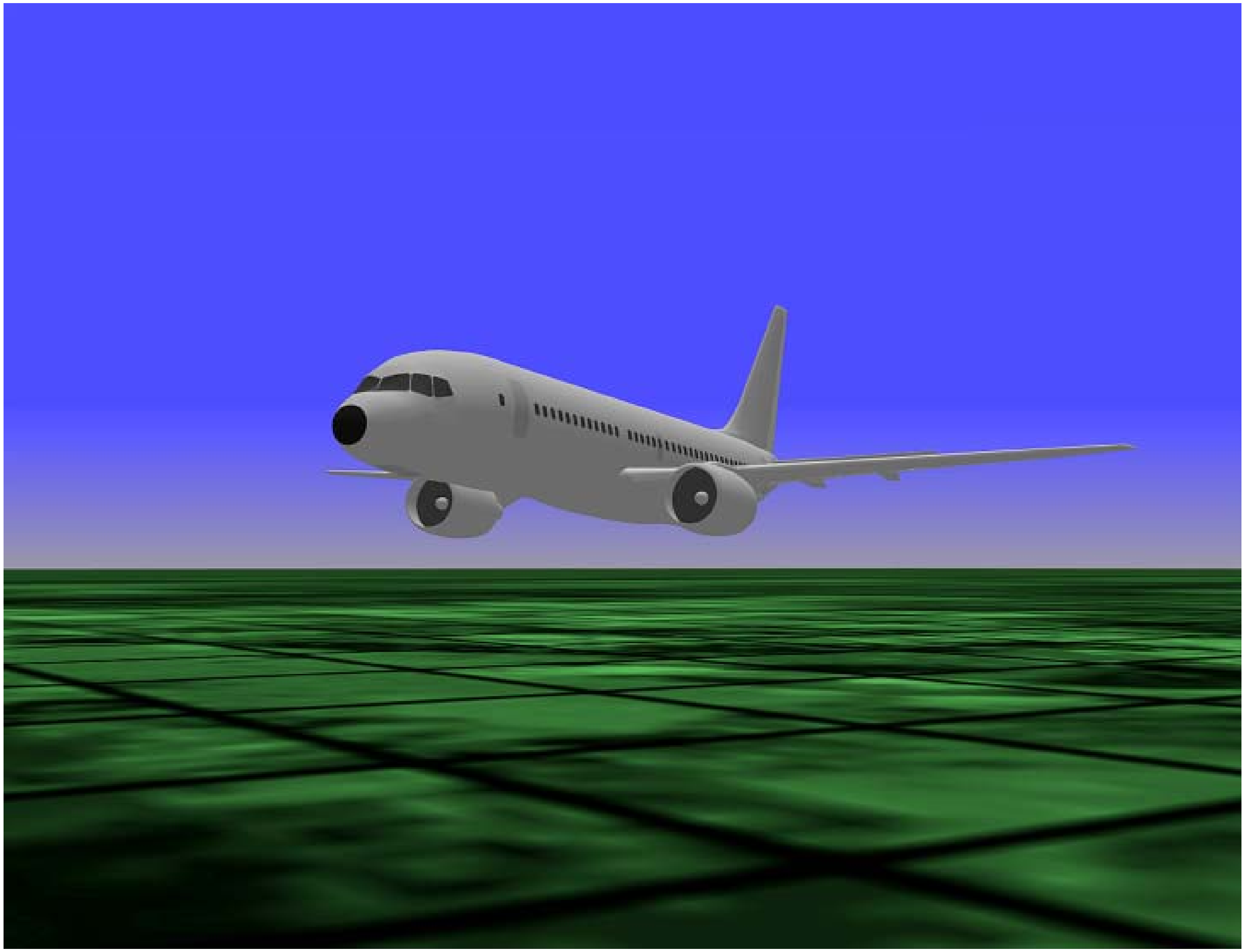


Figure 3-B.30

# Energy States

The term "energy state" describes how much of each kind of energy the airplane has available at any given time. Pilots who understand the airplane energy state will be in a position to know instantly what options they may have to maneuver their airplane.

The three sources of energy available to the pilot are

1. Kinetic energy, which increases with increasing airspeed.
2. Potential energy, which is approximately proportional to altitude.
3. Chemical energy, from the fuel in the tanks.

# The Three Sources of Energy Available to the Pilot Are

1. Kinetic energy, which increases with increasing speed
2. Potential energy, which is approximately proportional to altitude
3. Chemical energy, from the fuel in tanks

Figure 3-B.31

# Energy States (continued)

During maneuvering, these three types of energy can be traded, or exchanged, usually at the cost of additional drag. The relationships are shown here:

- Airspeed can be traded for altitude, and altitude can be traded for airspeed.
- Stored energy can be traded for either altitude or airspeed.

Modern high-performance, jet transport airplanes have low drag characteristics in cruise configuration; therefore, the pilot needs to exercise considerable judgement in making very large energy trades. A clean airplane operating near its limits can easily go from the low-speed boundary to and through the high-speed boundary very quickly. The process of controlling forces to change accelerations and produce a new energy state takes time. The longer time required by large airplanes requires that the pilot plan ahead—that much more—to achieve the final desired energy state. The objective is to manage energy so that kinetic energy stays between limits (stall and placards), the potential energy stays with limits (terrain to buffet altitude), and chemical energy stays above certain thresholds (not running out of fuel).

# Energy Relationships

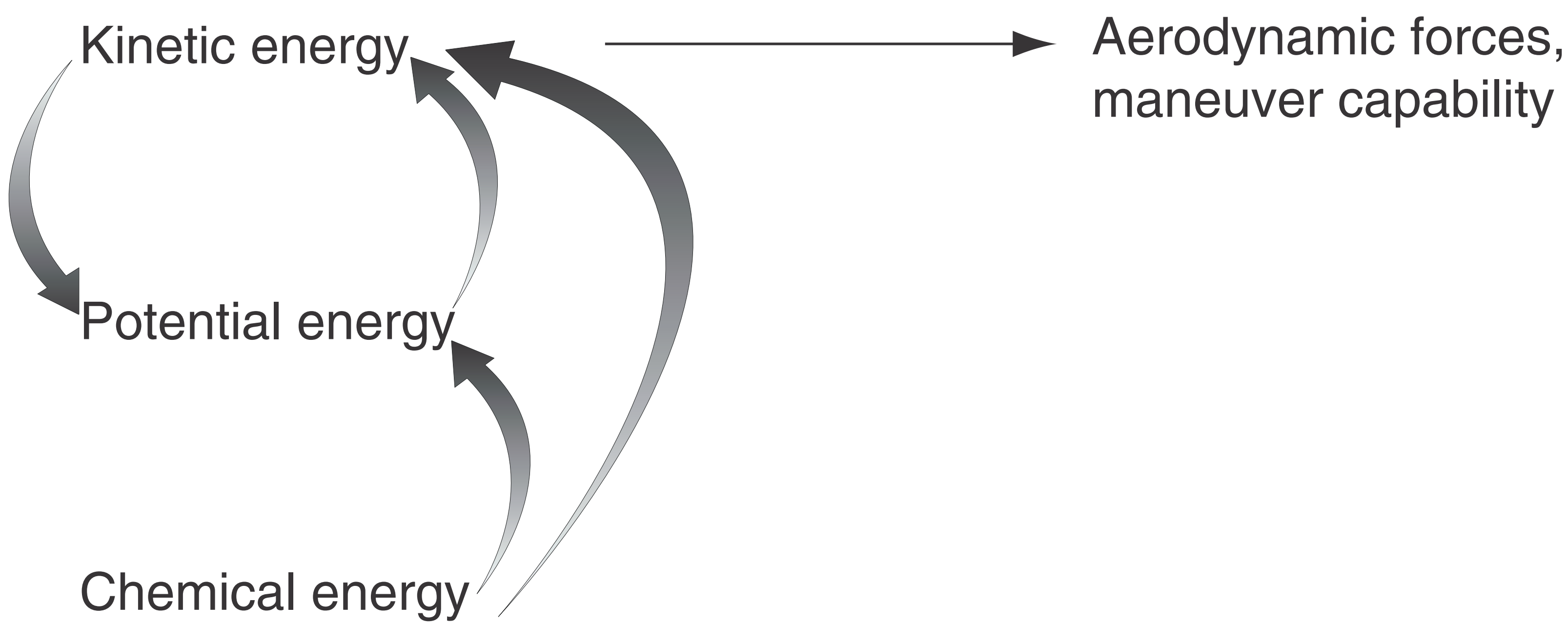



Figure 3-B.32

# Load Factors

Newton's second law, *force = mass x acceleration*, is the basis for discussing airplane load factors. Since the airplane has mass, if it is being accelerated there must be force acting on it. Conversely, if there is a force acting on an airplane, it will accelerate.

Acceleration refers to a change in either magnitude or direction of the velocity. It is convenient to refer to acceleration in terms of gravity, or simply, g's. The load factor expressed in g's is typically discussed in terms of components relative to the principal axes of the airplane:

- Longitudinal (fore and aft, typically thought of as speed change).
- Lateral (sideways).
- Vertical (or normal).

# Load Factors—Four Forces of Flight

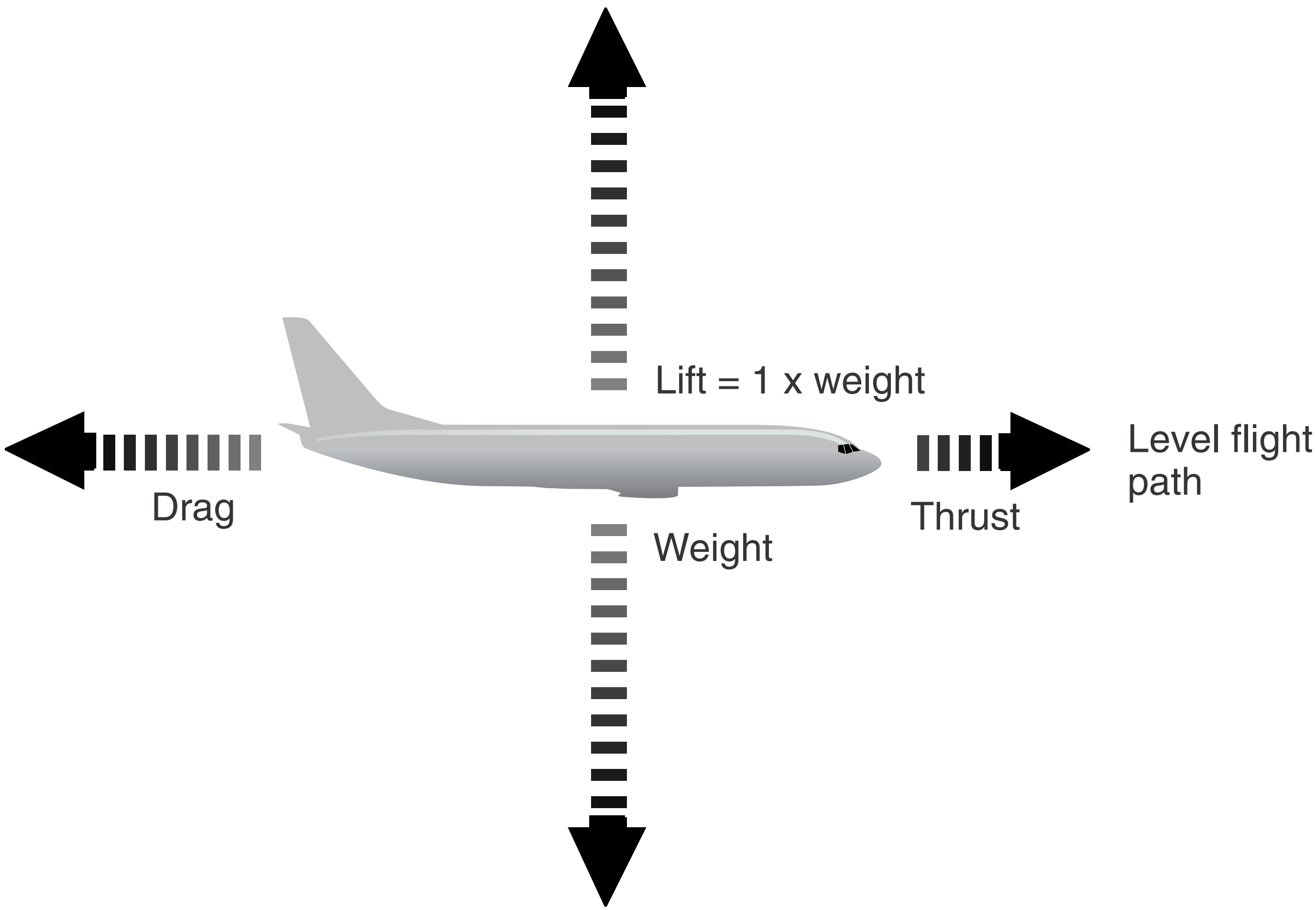



Figure 3-B.33

# Load Factors (continued)

In level flight, the vertical load factor is 1 times the acceleration due to gravity, or 1.0. In a pull-up, the load factor is above 1.0 and the flight path is curved. In a sustained vertical climb along a straight line, the thrust must be greater than the weight and drag. The wing and the load factor perpendicular to the airplane floor must be zero. Anything but zero will produce a curved flight path. Acceleration is a result of the sum of all forces acting on the airplane. One of these forces is always gravity, and gravity always produces an acceleration vector directed toward the center of the Earth. Aerodynamic forces are produced as a result of the orientation and magnitude of the velocity vector relative to the airplane, which are reduced into angles of attack and sideslip. It is the direction and speed of the airplane through the air that results in aerodynamic forces. More on these forces later.

# Load Factors—Airplane in Pull-Up

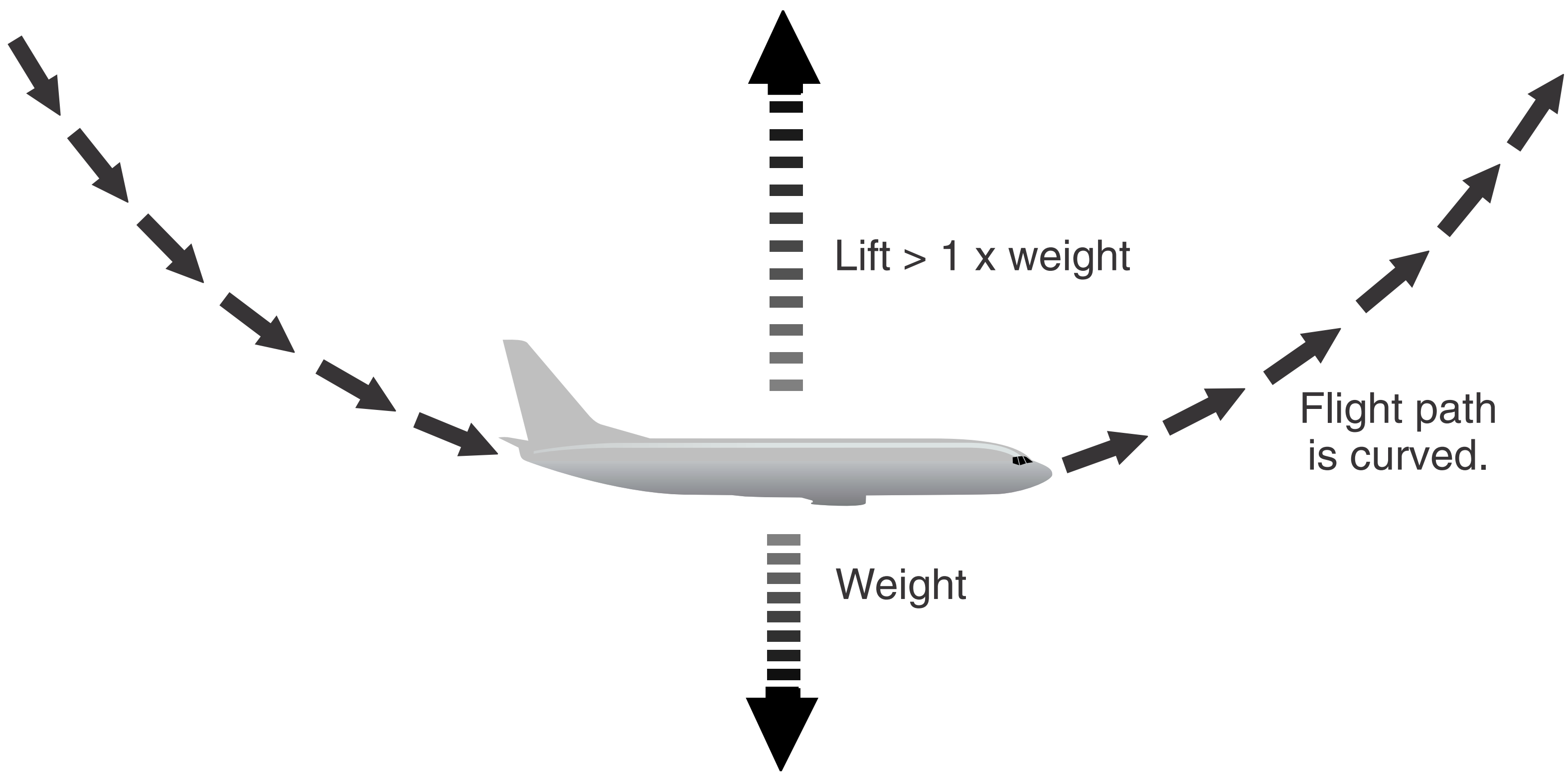
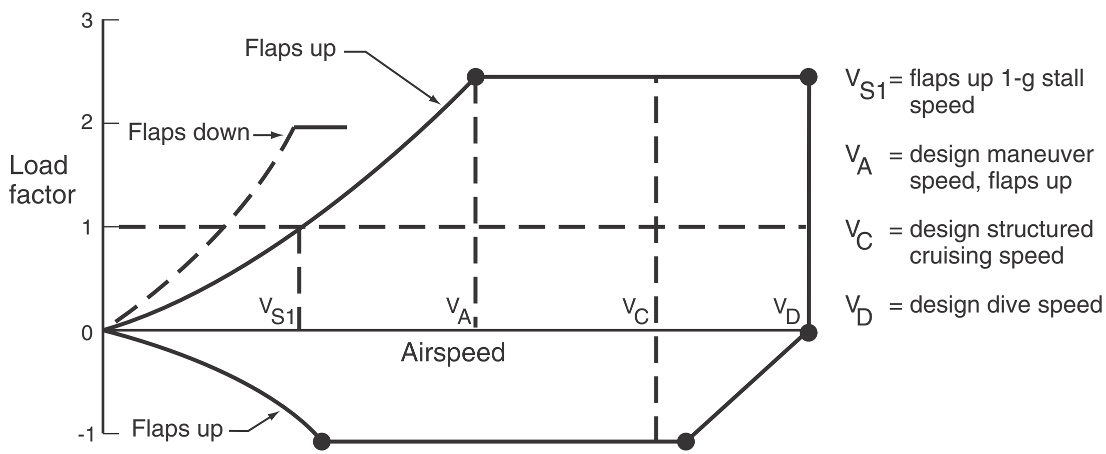



Figure 3-B.34

# Aerodynamic Flight Envelope

Current jet transport airplanes are certificated to withstand normal vertical load factors from -1.0 to 2.5 g in the cruise configuration. In addition to the strength of the structure, the handling qualities are demonstrated to be safe within these limits of load factors. The pilot should be able to maneuver safely to and from these load factors at these speeds, without needing exceptional strength or skills. Test pilots have evaluated the characteristics of airplanes in conditions that include inadvertent exceedances of these operational envelopes to demonstrate that the airplanes can be returned safely to the operational envelopes. This slide depicts a typical flight envelope, but it also shows the maximum demonstrated Mach and speed numbers. These are typically 0.05 to 0.07 Mach and 50 kn higher than the operational limits. Safe flight characteristics to return to the normal operational envelope must be demonstrated.

# Aerodynamic Flight Envelope



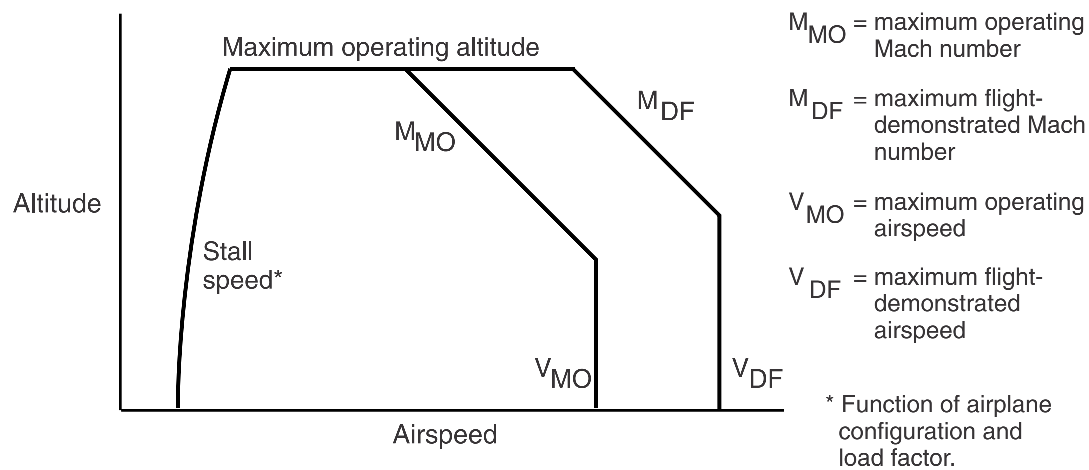




Figure 3-B.35

# Angle of Attack and Stall

Wing and tail surfaces all produce lift forces in the same way. The lift force generated by a surface is a function of the angle of attack, the dynamic pressure (proportional to the air density and the square of the true airspeed) of the air moving around it, and the size of the surface. It is important to understand the dependence of lift on angle of attack. As angle of attack is increased, lift increases proportionally up to the point where the air starts to separate from the wing. At this critical angle of attack, the airflow breaks down and the surface is stalled. This is true regardless of airplane speed or altitude. Angle of attack can sometimes be confusing.

The three angles usually referred to in the longitudinal axis are

- Angle of attack.
- Flight path angle.
- Pitch attitude.

These three angles and their relationships to each other are shown here. Depending on the context in which it is used, aerodynamicists use the term “angle of attack” in a number of different ways. Angle of attack is always the angle between the oncoming air or relative wind, and some reference line on the airplane or wing. Sometimes it is referenced to the chord line at a particular location on the wing, sometimes to an “average” chord line on the wing, other times it is referenced to a convenient reference line on the airplane, like the body reference x axis. Regardless of the reference, the concept is the same as are the consequences: exceed the critical angle of attack and the lifting surfaces and wind will separate, resulting in a loss of lift on those surfaces. Frequently the term “airplane angle of attack” is used to refer to the angle between the relative wind and the longitudinal axis of the airplane. In flight dynamics, this is frequently reduced to simply “angle of attack.” It is also the difference between the pitch angle and the flight path angle in a no-wind condition.

# Angle of Attack

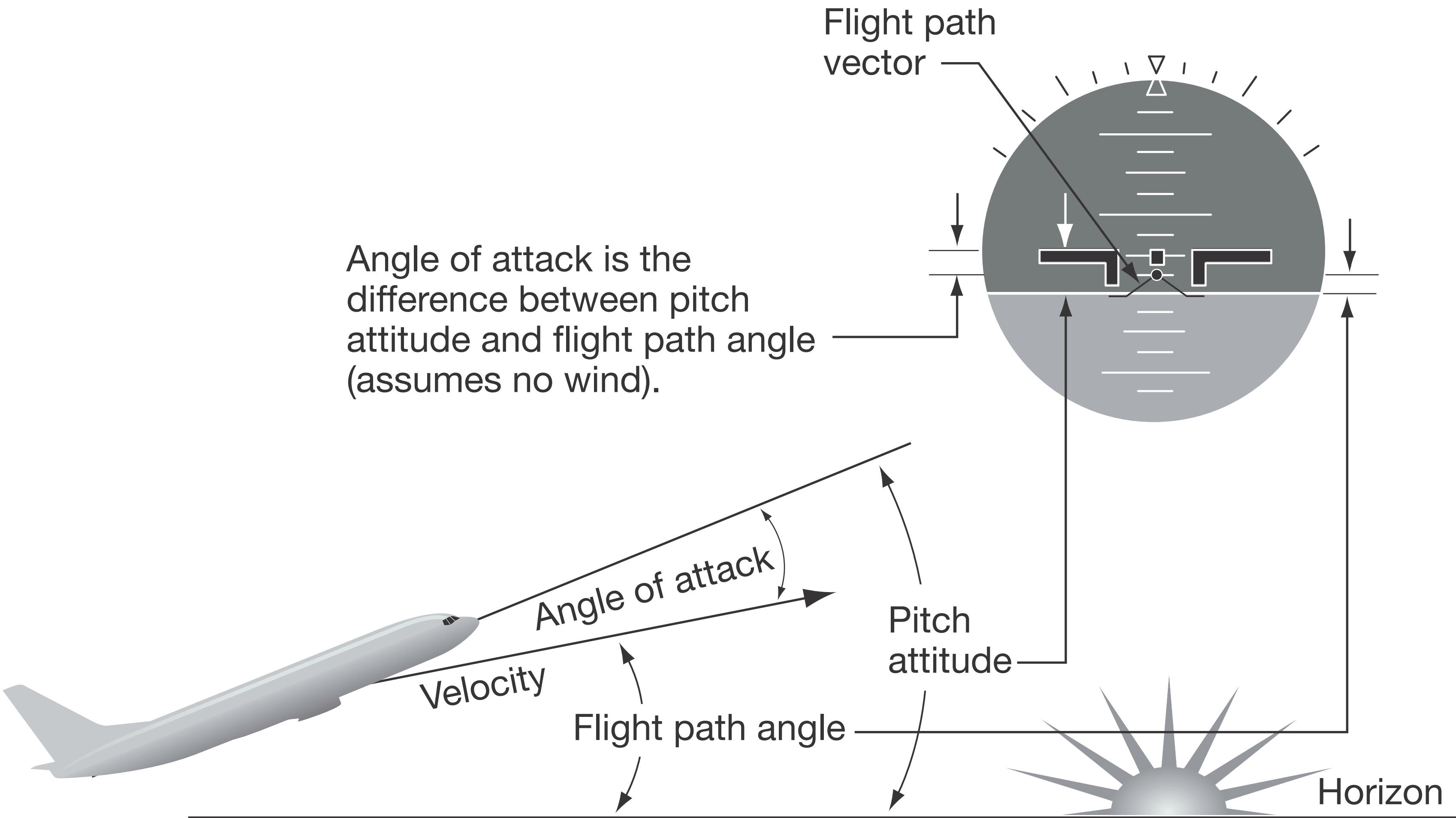



Figure 3-B.36

# Angle of Attack and Stall (continued)

The important point is that when the angle of attack is above the stall angle, the lifting capability of the surface is diminished. More importantly, an airplane can be stalled in any attitude and at any airspeed. The angle of attack determines whether the wing is stalled. A stall is characterized by any, or a combination, of the following:

- Buffeting.
- Lack of pitch authority.
- Lack of roll control.
- Inability to arrest the descent rate.

A stall must not be confused with an approach-to-stall warning that occurs before the stall. Stall speeds are published in the Approved Flight Manual (AFM). It should be remembered, however, that these speeds are based on precisely defined flight conditions. In conditions other than these, the stall speed can be considerably different. Many airplane upsets are quite dynamic and involve elevated load factors and large speed-rate changes. It should also be noted that the critical angle of attack is reduced at higher Mach numbers (higher altitude).

# Stalls

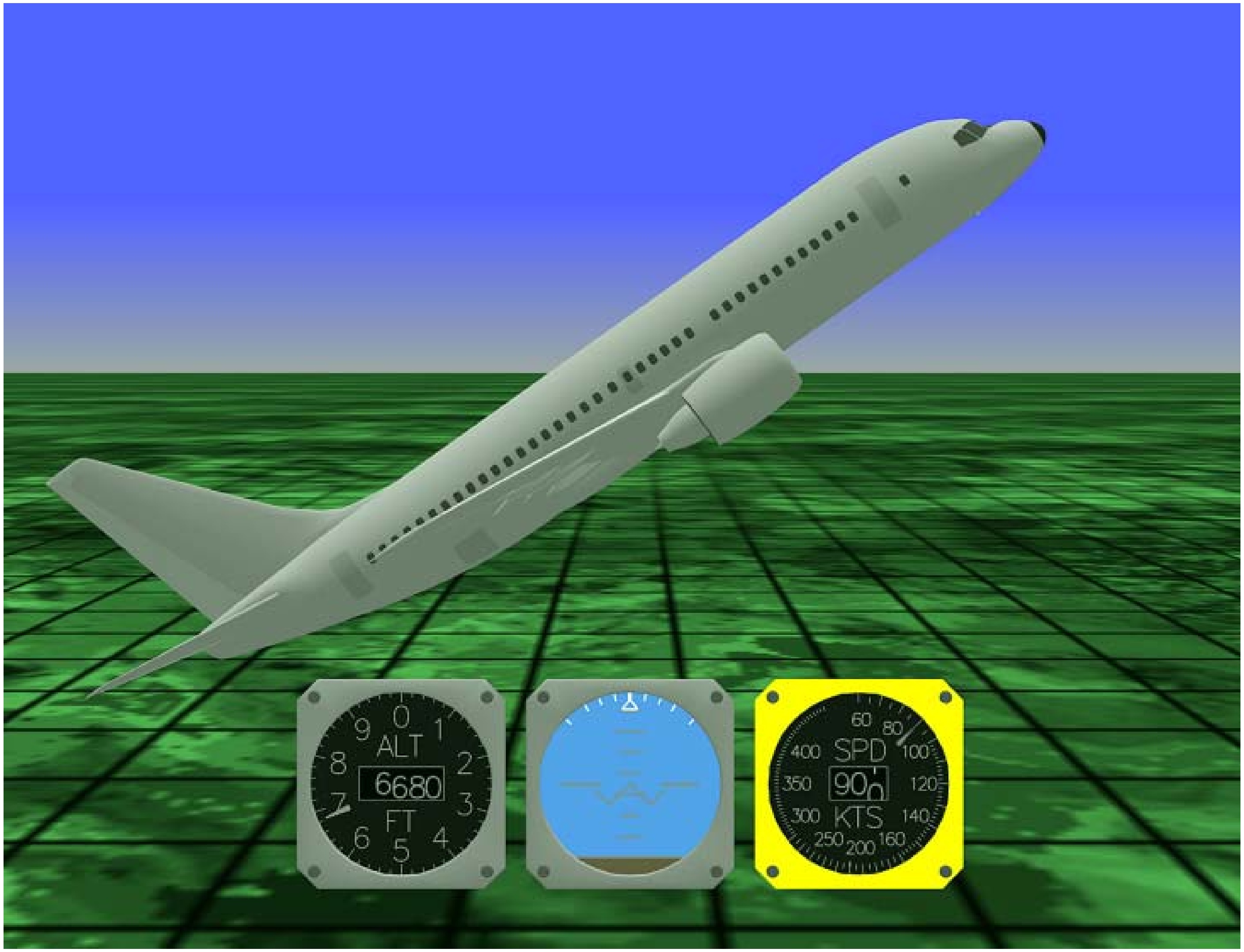



Figure 3-B.37

# Camber

Camber is illustrated here and refers to the amount of curvature evident in an airfoil shape. Airfoils with camber are more efficient at producing lift than those without. Airfoils with specific kinds of camber are more efficient in specific phases of flight. For example, aerobatic airplanes usually employ symmetrical airfoils. These work well for that purpose, but are not efficient in cruise flight. The fixed camber of a lifting surface is built into the lifting surface, depending on the airplane's main function. There are, of course, many ways to change a surface's camber in flight.

# Camber

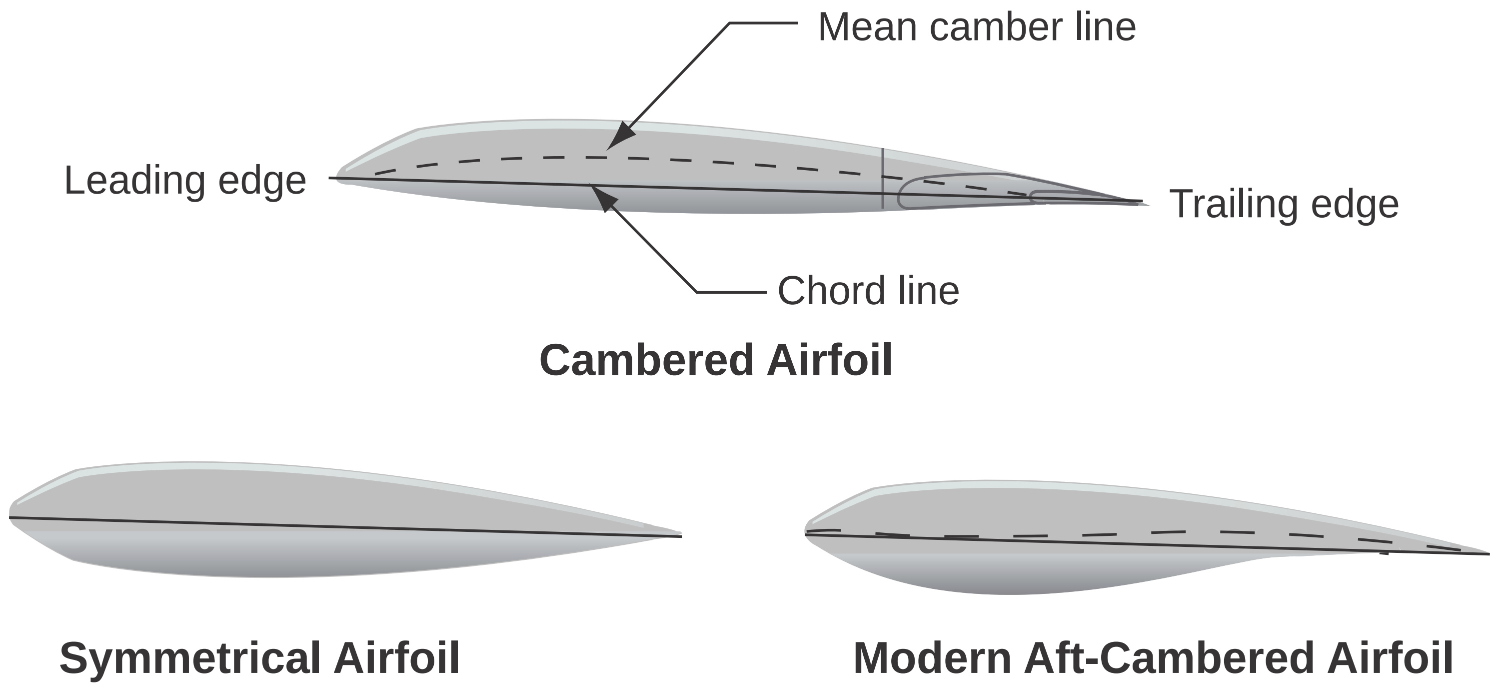



Figure 3-B.38

# Control Surface Fundamentals

Trailing edge control surfaces provide a way of modulating the lift on a surface without physically changing that surface's angle of attack. The aerodynamic effect is that of increasing the lift at a constant angle of attack for trailing edge down deflection. As you can see, the price paid is a reduced angle of attack for stall at higher deflection angles. Large downward aileron deflections, at very high angles of attack, could induce air separation over that portion of the wing. Reducing the angle of attack before making large aileron deflections will help ensure the effectiveness of those surfaces.

# Trailing Edge Control Surfaces

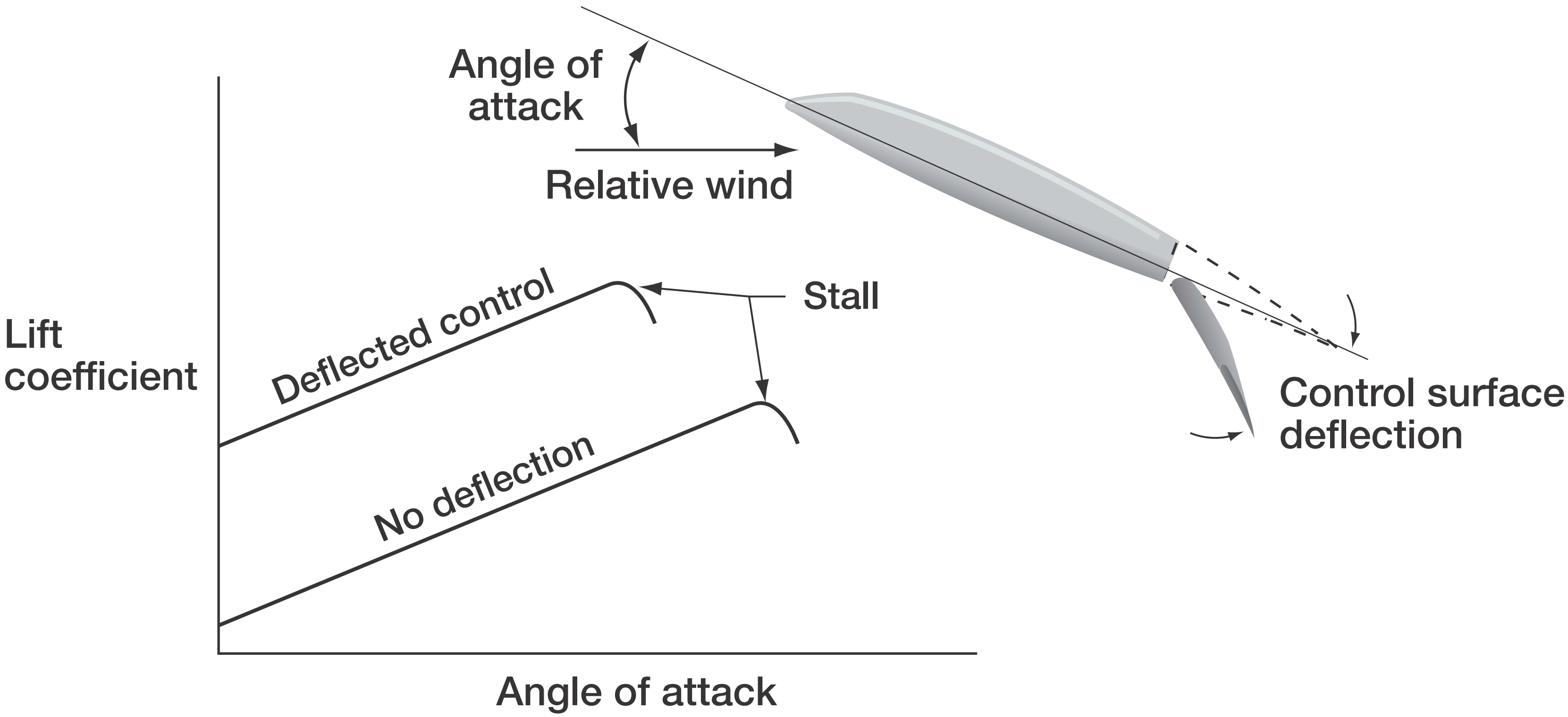



Figure 3-B.39

# Spoiler-Type Devices

Spoilers serve a dual purpose:

- Spoiling wing lift.
- Generating additional drag.

Spoilers separate airflow and stall the wing locally. Their effectiveness depends on how much lift the wing is generating. If the wing is producing large amounts of lift, as in the case of the flaps extended and at moderate angles of attack, the spoilers become effective control devices because there is more lift to spoil. Conversely, if the airflow is already separated, putting a spoiler up will not induce any more separation. As was the case with aileron control surfaces, the wing must be unstalled in order for the aerodynamic controls to be effective.

# Spoiler Devices

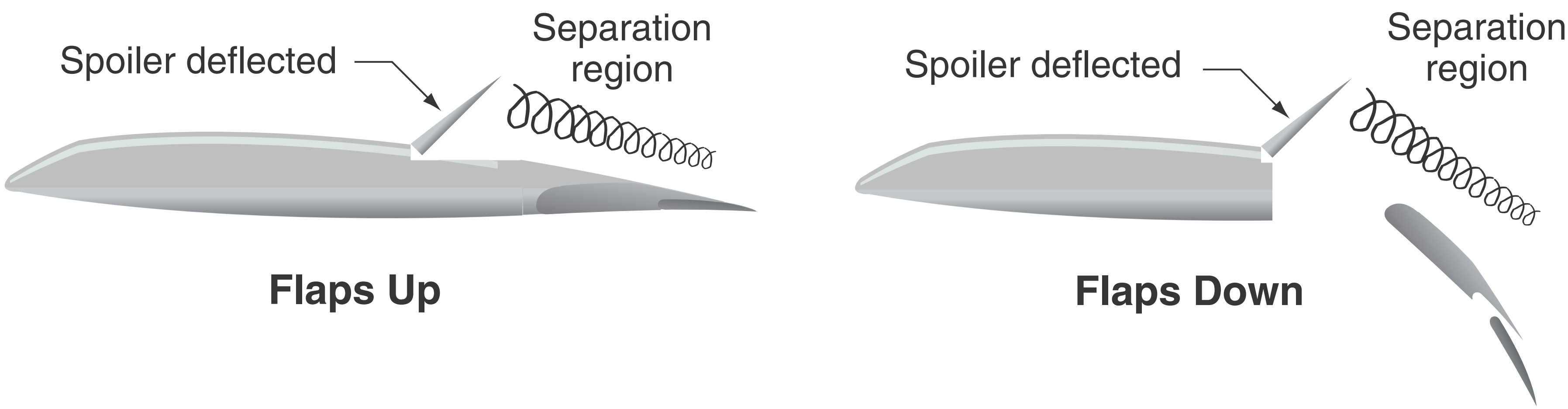



Figure 3-B.40

# Trim

“Trim” is defined as that condition in which the forces on the airplane are stabilized and the moments about the center of gravity all add up to zero.

“Pilot Trim” is that condition in which the pilot can release the controls and the airplane will continue to fly in the manner desired.

In the pitch axis, trim is achieved by varying the lift on the horizontal tail/elevator combination to balance the pitching moments about the center of gravity. Traditionally, there have been three ways of doing that:

1. Fixed stabilizer/trim: Maneuver limitations if trimmed near a deflection limit.

2. The all-flying tail: Requires powerful, fast-acting, irreversible flight control systems.

3. Trimmable stabilizer: From a trimmed position, full elevator authority is available.

# Trim

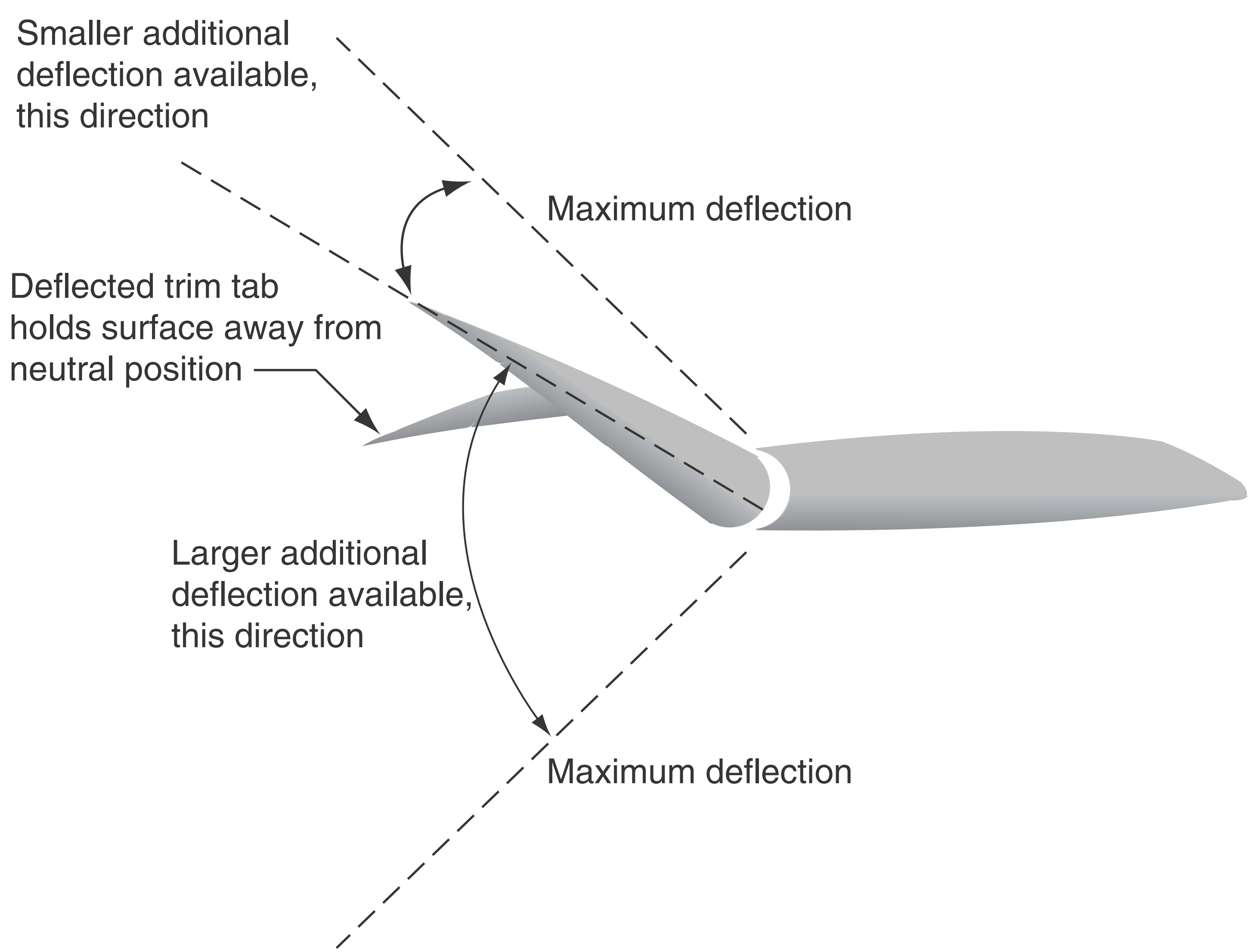



Figure 3-B.41

# Lateral and Directional Aerodynamic Considerations

The static lateral stability of an airplane involves consideration of rolling moments due to sideslip.

Aerodynamically, anti-symmetric flight, or flight in sideslip, can be quite complex. The forces and moments generated by the sideslip can affect motion in all three axes of the airplane. As will be seen, sideslip can generate strong aerodynamic rolling moments as well as yawing moments. In particular the magnitude of the coupled roll-due-to-sideslip is determined by several factors. Among them are

- Wing dihedral effects.
- Angle of sideslip.
- Pilot-commanded sideslip.

# Lateral and Directional Aerodynamic Considerations

**The magnitude of coupled roll-due-to-sideslip is determined by several factors, including**

- **Wing dihedral effects**
- **Angle of sideslip**
- **Pilot-commanded sideslip**

Figure 3-B.42

# Wing Dihedral Effects

Dihedral is the positive angle formed between the lateral axis of an airplane and a line that passes through the center of the wing. A wing with dihedral will develop stable rolling moments with sideslip, and it contributes to the lateral stability of an airplane. The term “dihedral effect” is used when describing the effects of wing sweep and rudder on lateral stability and control. Wing sweep is beneficial for high-speed flight because it will delay compressibility effects. Wing sweep also contributes to the dihedral effect. A sideslip on a swept-wing airplane results in a larger rolling moment than on a straight-wing airplane. Rudder input produces sideslip and contributes to the dihedral effect. The effect is proportional to the angle of sideslip. At high angles of attack, aileron and spoiler roll controls become less effective. The rudder is still effective; therefore, it can produce large sideslip angles, which in turn produces roll because of the dihedral effect.

# Wing Dihedral Angle

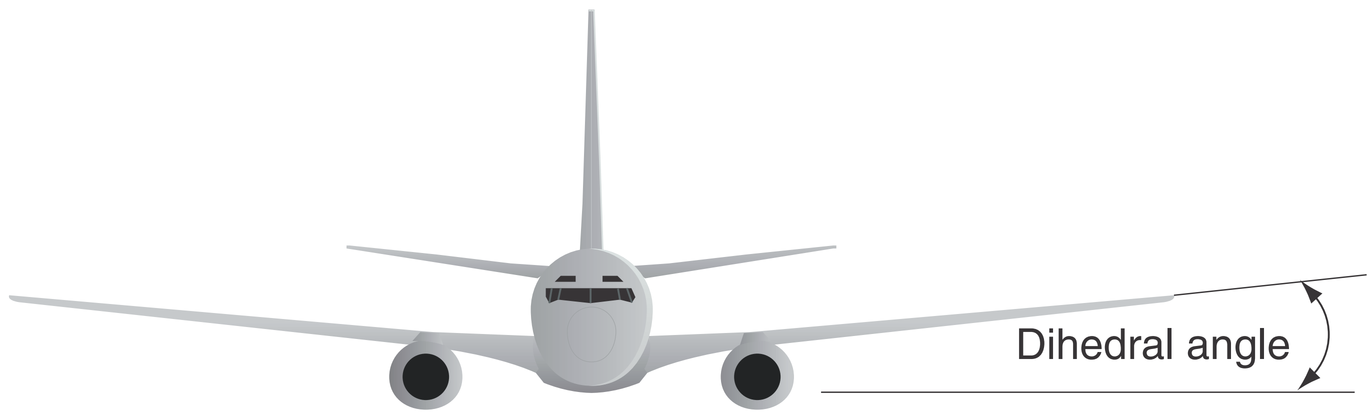



Figure 3-B.43

# Pilot-Commanded Sideslip

The rudders on modern transport jets are sized to counter the yawing moment associated with engine failure at very low takeoff speeds. It is important to realize that these powerful rudder inputs are available whether or not an engine has failed. Large rolling moments are possible through the rudder. “Crossover speed” is a recently coined term that describes the lateral controllability of an airplane with rudder at a fixed (up to maximum) deflection. It is the minimum speed (weight and configuration dependent) in 1-g flight where maximum aileron/spoiler input is reached and the wings are still level or at an angle to maintain directional control. Any additional rudder input or decrease in speed will result in an unstoppable roll into the direction of the deflected rudder. Crossover speed is weight and configuration dependent, but more importantly, it is sensitive to angle of attack. The crossover speed will increase with increased angle of attack. In an airplane upset due to rudder deflection with large and increasing bank angle and the nose rapidly falling below the horizon, the input of additional noseup elevator with already maximum input of aileron/spoilers will only aggravate the situation. The correct action is to unload the airplane to reduce the angle of attack to regain aileron/spoiler effectiveness. This action may not be intuitive and will result in a loss of altitude.

The rudder should not normally be used to induce roll through sideslip because transient sideslip can induce very rapid roll rates with significant time delay. The combination of rapid roll rates and the delay can startle the pilot, which in turn can cause the pilot to overreact in the opposite direction. The overreaction can induce abrupt yawing movements and violent out-of-phase roll rates, which can lead to successive cyclic rudder deflections, known as rudder reversals. Rapid full-deflection flight control reversals can lead to loads that can exceed structural design limits.

# Angle of Slideslip

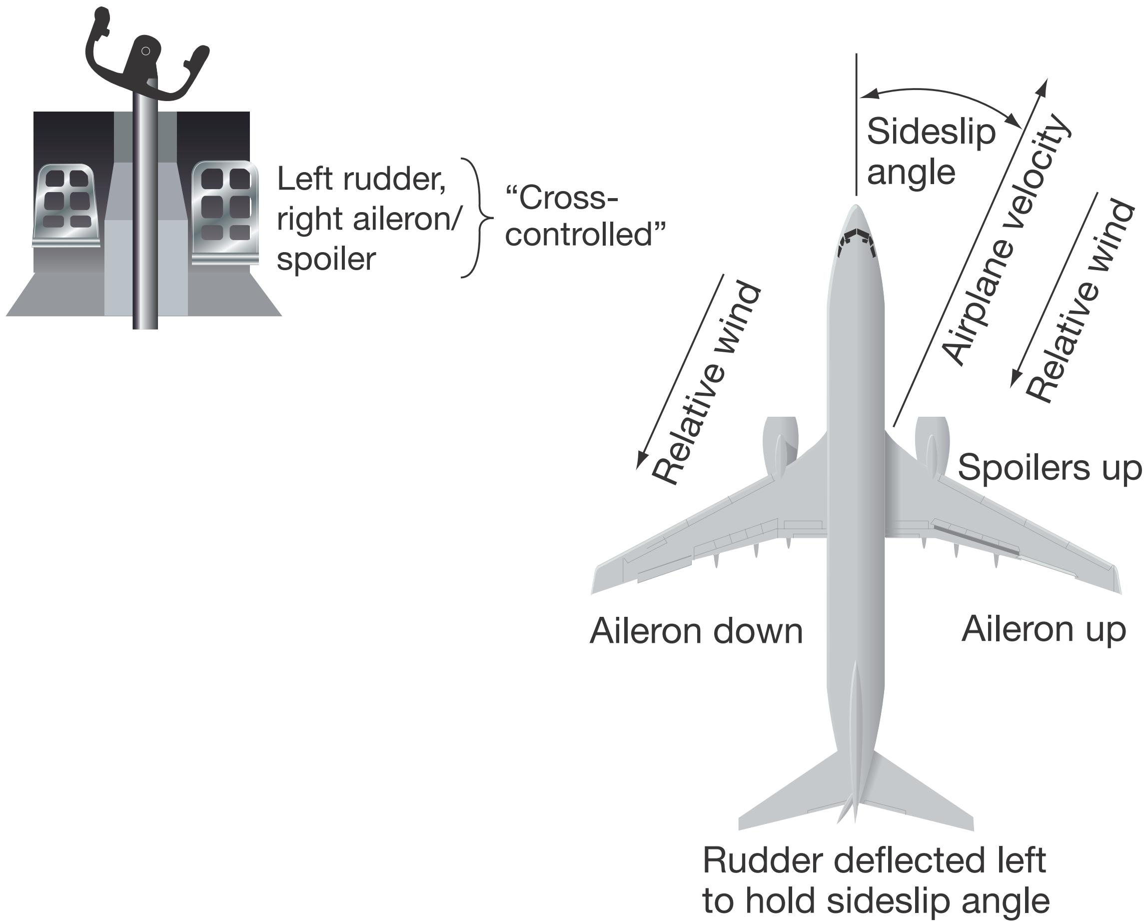


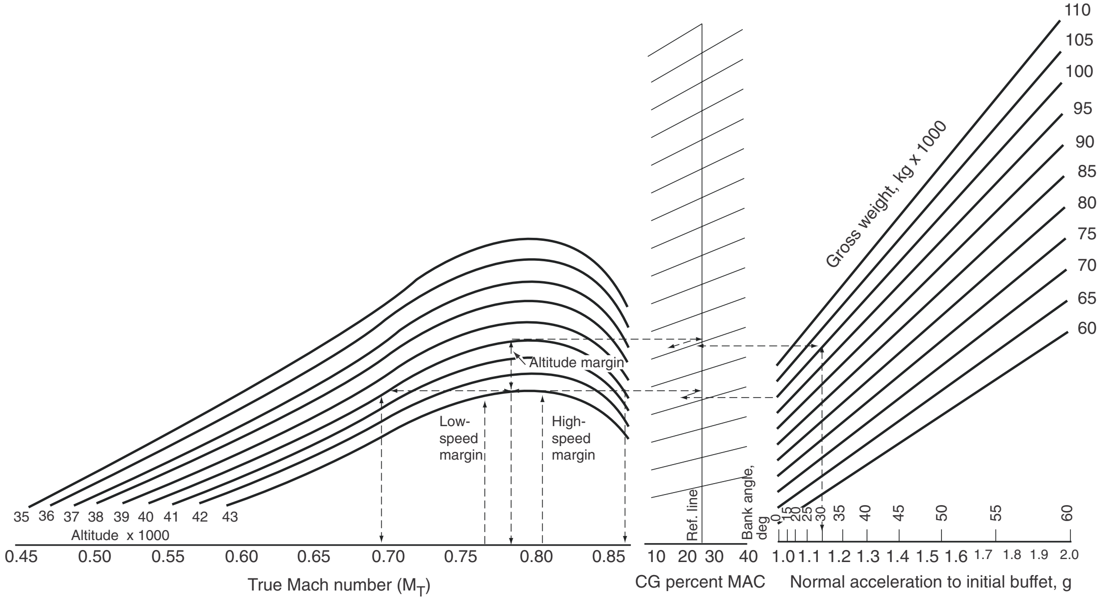

Figure 3-B.44

# High-Speed, High-Altitude Characteristics

Aerodynamic characteristics of lifting surfaces are significantly affected by the ratio of airspeed to the speed of sound (expressed as Mach number). At high altitudes, large Mach numbers exist at relatively low calibrated airspeeds. As Mach number increases, airflow over parts of the airplane begins to exceed the speed of sound. Shock waves, associated with this local supersonic flow, can interfere with the normally smooth flow over the lifting surfaces. Depending on the airplane, characteristics such as pitchup, pitchdown, or aerodynamic buffeting may occur. The point at which buffeting would be expected to occur is documented in the AFM. A sample chart is shown here. Some airplanes have broad speed margins; some have abrupt high-speed buffet margins; and some have narrow, "peaky" characteristics, as depicted here. Pilots should become familiar with the buffet boundaries. These boundaries let the pilot know how much maneuvering room is available.

- Airplane A has wide speed range but narrow g.
- Airplane B has narrow speed range but larger g.
- Airplane C has greater margin at slower speeds.

# High-Speed, High-Altitude Characteristics



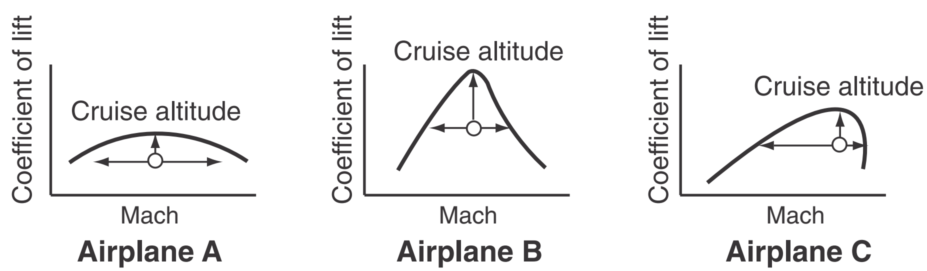




Figure 3-B.45

# Static Stability

Positive static stability is defined as the initial tendency to return to an undisturbed state after a disturbance. This concept is illustrated here and can apply to a number of different parameters, all at the same time. These include, but are not limited to

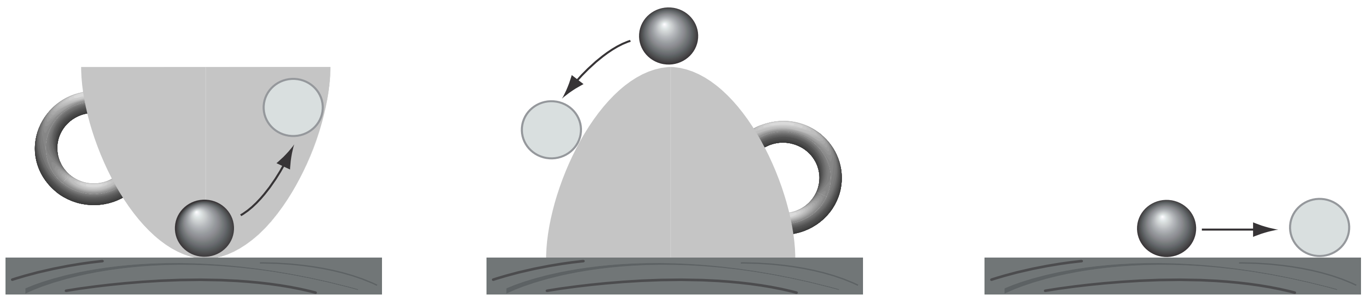
- Speed stability: returning to initial trim airspeed after a disturbance.
- Mach number stability: maintaining Mach number although speed changes.
- Load factor stability: returning to trimmed g load if disturbed.

Two important aspects of stability are that it

1. Allows for some unattended operation.
2. Gives tactile feedback to the pilot.

For example, if the pilot is holding a sustained pull force, the speed is probably slower than the last trim speed.

# Static Stability



**Stable**

When ball is displaced, it returns to its original position.

**Unstable**

When ball is displaced, it accelerates from its original position.

**Neutral**

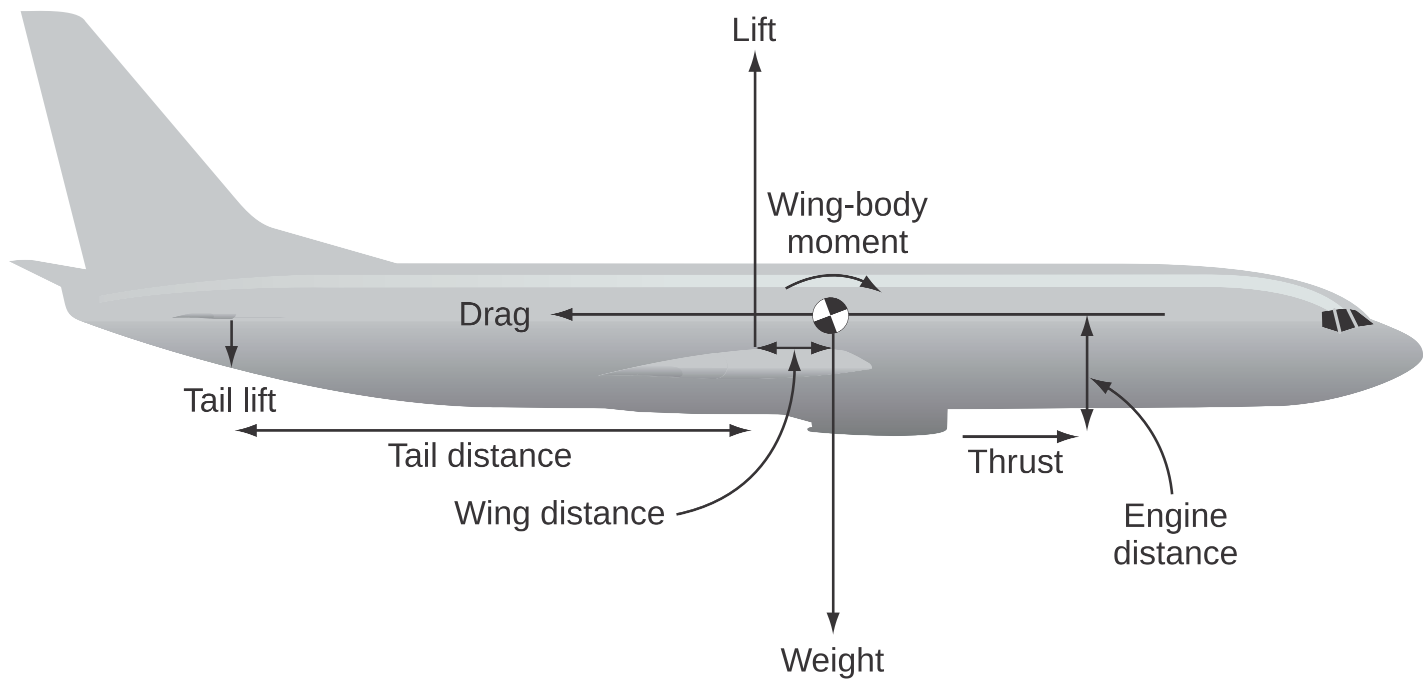
When ball is displaced, it neither returns, nor accelerates away—it just takes up a new position.

Figure 3-B.46

# Maneuvering in Pitch

Controlling pitching motions involves controlling aerodynamic and other moments about the center of gravity to modulate the angle of attack. Other than thrust moments, the pilot controls the pitching moments (angle of attack) by means of the stabilizer and elevator. Moments have dimensions of force times distance. We are concerned with moments about the center of gravity. The various pitching moments, and how they are calculated, are shown here. In steady flight, the moments about the center of gravity, as well as the forces, are all balanced. The difference between the center of gravity and the center of lift is balanced by tail loading. Essentially, the pilot controls the amount of lift generated by the horizontal tail by moving the elevator, which adjusts the angle of attack and modulates the amount of lift that the wing generates. Engines are rarely aligned with the center of gravity; therefore, pitching moments will be created with changes in thrust. As long as the angle of attack is within unstalled limits and the airspeed is within limits, the aerodynamic controls will work to maneuver the airplane in the pitch axis as described. This is true regardless of the attitude of the airplane or the orientation of the weight vector.

# Maneuvering in Pitch




$$(\text{Moment})_{\text{Tail}} + (\text{Moment})_{\text{Lift}} + (\text{Moment})_{\text{Thrust}} + (\text{Moment})_{\text{Wing-body}} = \text{Total pitching moment}$$

$$\left(\text{Tail lift} * \text{Tail distance}\right) + \left(\text{Wing lift} * \text{Wing distance}\right) + \left(\text{Thrust} * \text{Engine distance}\right) + (\text{Moment})_{\text{Wing-body}} = \text{Total pitching moment}$$

Figure 3-B.47

# Mechanics of Turning Flight

Recalling Newton's second law, that an object in motion will continue in a straight line unless acted on by an external force, consider what is required to make an airplane turn. A force perpendicular to the flight path, in the direction of turn, is required. As depicted, part of the lift vector is lost, and there is an imbalance in forces. Unless the lift vector is increased, so that its vertical component equals the weight of the airplane, the aircraft will begin to accelerate toward the Earth (descend). All of this is well-known to pilots, but it bears reiteration in the context of recovery from extreme airplane upsets. If the objective is to arrest descent, maneuvering in pitch if the wings are not level will only cause a tighter turn and, depending on the bank angle, may not contribute significantly to generating a lift vector that points away from the ground. Indeed, to maintain level flight at bank angles beyond 66 deg requires a larger load factor than 2.5 g. Knowledge of these relationships is useful in other situations as well. In the event that the load factor is increasing, excess lift is being generated, and the pilot does not want the speed to decrease, bank angle can help to keep the flight path vector below the horizon, getting gravity to help prevent loss of airspeed. The excess lift can be oriented toward the horizon and, in fact, modulated up and down to maintain airspeed.

# Mechanics of Turning Flight

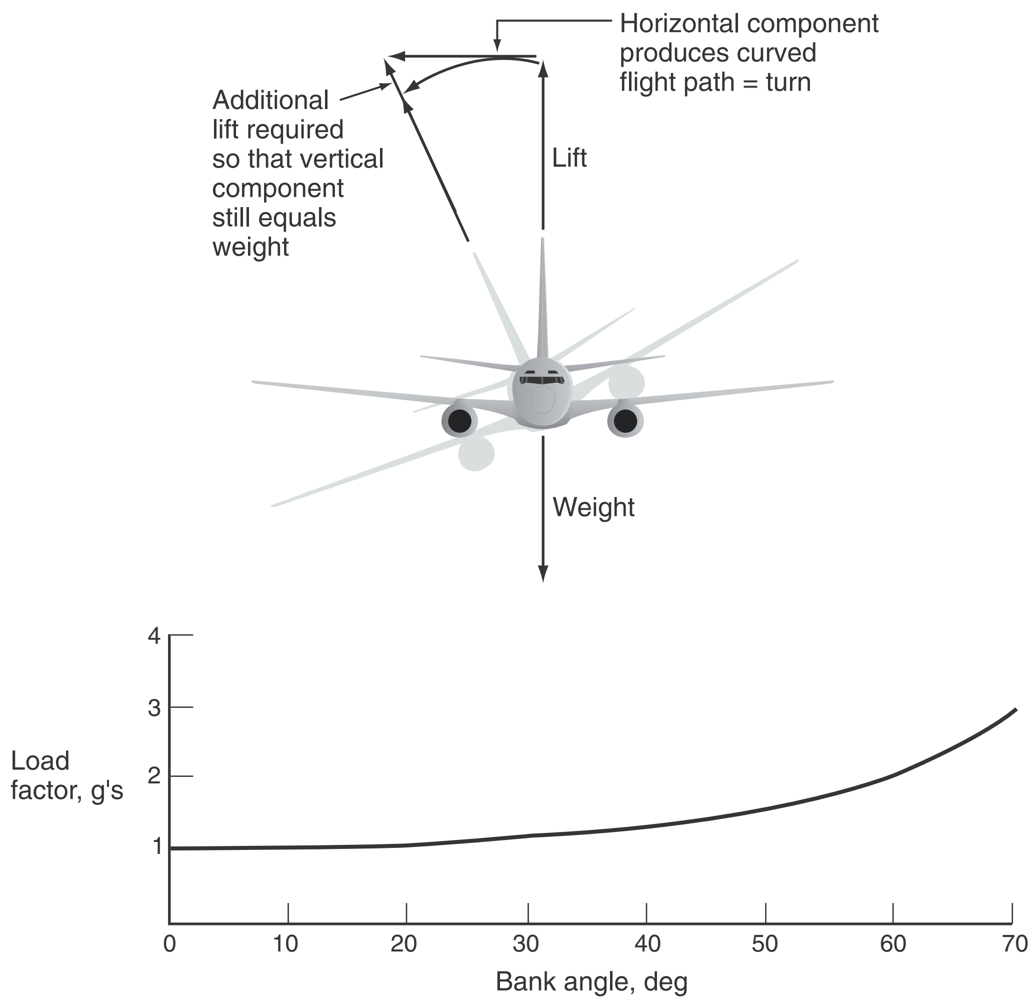



Figure 3-B.48

# Lateral Maneuvering

Motion about the longitudinal axis is called roll. On modern jet airplanes, the specific deflection combinations of ailerons and spoilers are designed to make adverse yaw virtually undetectable to the pilot. As discussed before, trailing edge control surfaces lose effectiveness in the downward direction at high angles of attack. Spoilers also lose their effectiveness as the stall angle of attack is exceeded. Transport aircraft are certificated to have the capability of producing and correcting roll up to the time the airplane is stalled. Beyond the stall angle, no generalizations can be made. For this reason, it is critical to reduce the angle of attack at the first indication of stall so that control surface effectiveness is preserved. As discussed before, airplanes of large mass and large inertia require that pilots be prepared for longer response time and plan appropriately.

# Lateral Maneuvering—Roll Axis

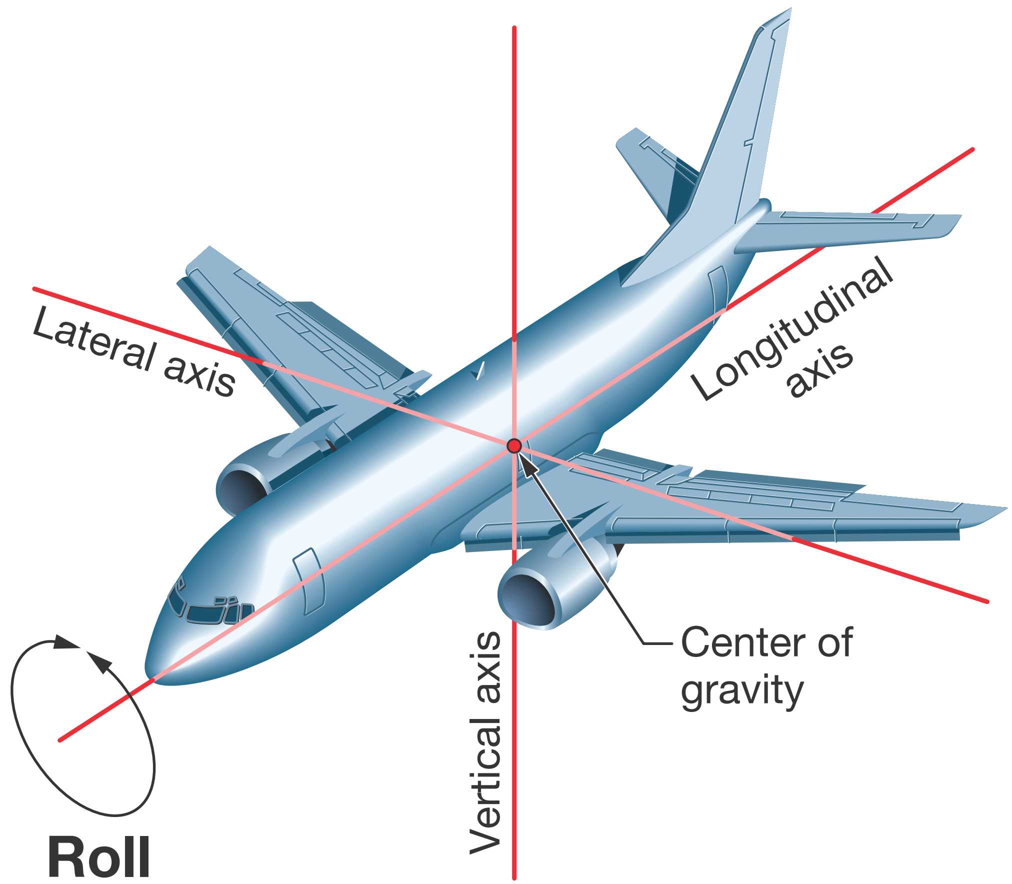



Figure 3-B.49

# Lateral Maneuvering—Flight Dynamics

From a flight dynamics point of view, the greatest power of lateral control in maneuvering the airplane—using available energy to maneuver the flight—is to orient the lift vector. In particular, pilots need to be aware of their ability to orient the lift vector with respect to the gravity vector. Upright with wings level, the lift vector is opposed to the gravity vector, and the vertical flight path is controlled by longitudinal control and thrust. Upright with the wings not level, the lift vector is not aligned with gravity, and the flight path will be curved in the downward direction if the g force is not increased above 1. In all cases, the pilot should ensure that the angle of attack is below the stall angle and roll to upright as rapidly as possible.

# Lateral Maneuvering—Flight Dynamics

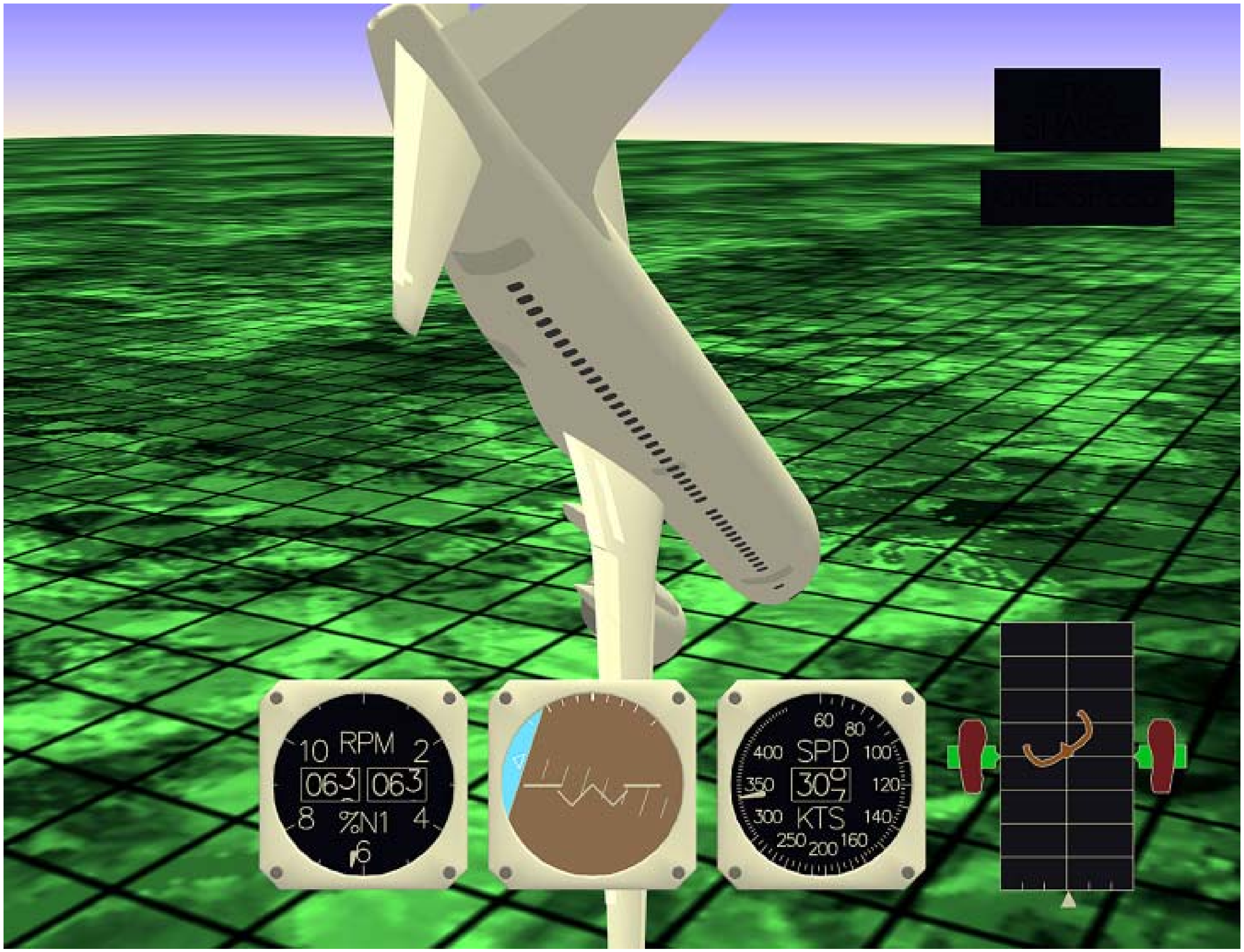



Figure 3-B.50

# Directional Maneuvering

Motion about the vertical axis is called yaw. The principal controller of aerodynamic moments about the vertical axis is the rudder, but it is not the only one. Others include asymmetric thrust and asymmetric drag. Generally, the rudder is used to control yaw in a way that minimizes sideslip. On modern jet transports with powerful engines located away from the centerline, engine failure can result in very large yawing moments. Rudders are sized to cope with these moments down to very low speeds. In a condition of no engine failure, very large yawing moments would result in very large sideslip angles and large structural loads, should the pilot input full rudder when it is not needed. There are a few cases, however, when it is necessary to generate sideslip—crosswind landing, for example. Although stability in the directional axis tends to drive the sideslip angle toward zero, without augmented stability (yaw damping) the inertial and aerodynamic characteristics of modern jet transports would produce a rolling and yawing motion known as “Dutch roll.” The pilot, with manual control over rudder deflection, is the most powerful element in the system.

# Directional Maneuvering—Yaw Axis

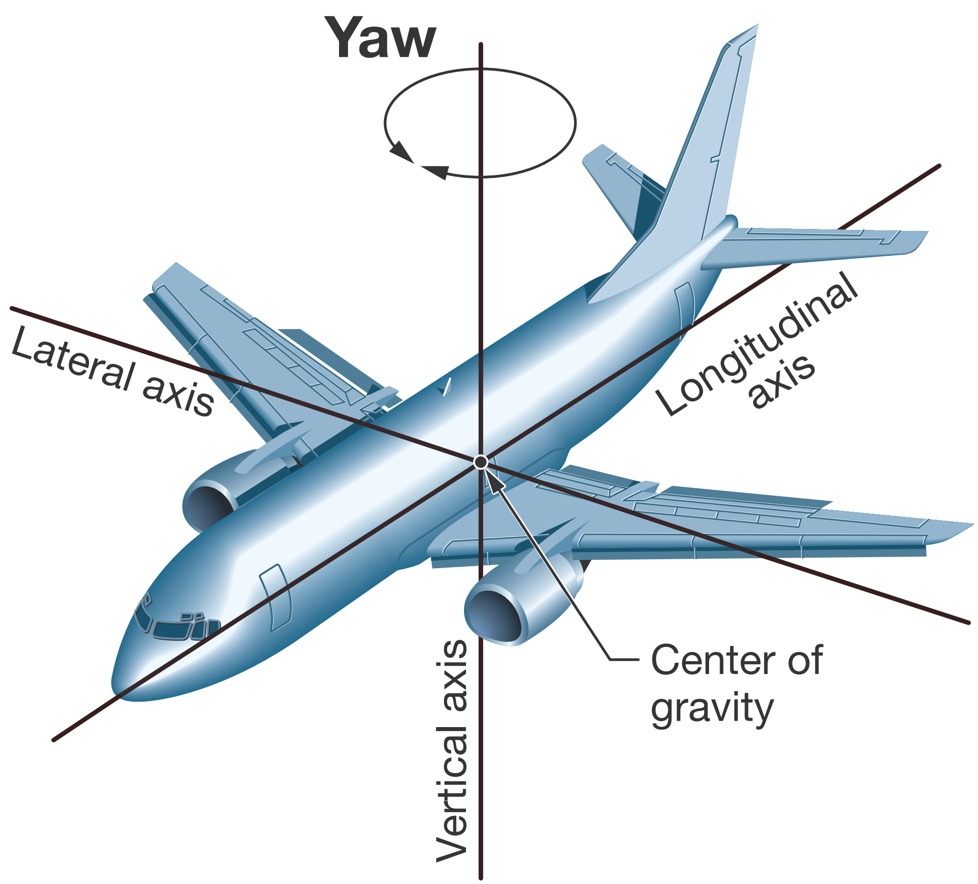



Figure 3-B.51

# Flight at Extremely Low Airspeeds

It is possible for the airplane to be flown at speeds below the defined stall speed. This regime is outside the certified flight envelope. At extremely low airspeed, there are several important effects for the pilot to know about. Lift generated by wings and tails depends on both the angle of attack and the velocity of the air moving over the surfaces. At very low airspeeds, an unstalled surface will produce lift. The lift generated may not be enough to support the weight of the airplane. In the case of the lift generated by the tail, at very low airspeed, it may not be great enough to trim the airplane, that is, to keep it from pitching. The trajectory will be largely ballistic, and it may be difficult to command a change in attitude until gravity produces enough airspeed to generate sufficient lift—that is only possible at angles of attack below the stall angle. For this reason, if airspeed is decreasing rapidly, it is very important to reduce angle of attack and use whatever aerodynamic forces are available to orient the airplane so that a recovery may be made when sufficient forces (airspeed) are available.

# Flight at Extremely Low Airspeeds


Figure 3-B.52

# Flight at Extremely Low Airspeeds (continued)

The situation becomes only slightly more complicated when thrust is considered. With engines offset from the center of gravity, thrust produces both forces and moments. As airspeed decreases, engine thrust generally increases for a given throttle setting. With engines below the center of gravity, there will be a noseup moment generated by engine thrust. Especially at high power settings, this may contribute to even higher noseup attitudes and even lower airspeeds.

Pilots should be aware that, as aerodynamic control effectiveness diminishes with lower airspeeds, the forces and moments available from thrust become more evident, and until the aerodynamic control surfaces become effective, the trajectory will depend largely on inertia and thrust effects.

# Flight at Low Airspeeds and Thrust Effects


Figure 3-B.53

# Flight at Extremely High Speeds

Inadvertent excursions into extremely high speed, either Mach or airspeed, should be treated very seriously. Flight at very high Mach numbers puts the airplane in a region of reduced maneuvering envelope. Pilots need to be aware that the envelope is small. Prudent corrective action is necessary to avoid exceeding limits at the other end of the envelope, should an inadvertent excursion occur. Flight in the high-airspeed regime brings with it an additional consideration of very high control power. At speeds higher than maneuver speed, very large deflection of the controls has the potential to generate structural damage.

In either the Mach or airspeed regime, if speed is excessive, the first priority should be to reduce speed to within the normal envelope. Many tools are available for this, including orienting the lift vector away from the gravity vector; adding load factor, which increases drag; reducing thrust; and adding drag by means of the speedbrakes. The single most powerful force the pilot has available is the wing lift force. The second largest force acting on the airplane is the weight vector. Getting the airplane maneuvered so that the lift vector points in the desired direction should be the first priority, and it is the first step toward managing the energy available in the airplane.

# Flight at Extremely High Speeds


Figure 3-B.54

# Summary of Swept-Wing Fundamentals for Pilots

- Flight dynamics: Newton’s laws.
- Energy states: kinetic, potential, and chemical.
- Load factors: longitudinal, lateral, and vertical.
- Aerodynamic flight envelope: operating and demonstrated speeds.
- Aerodynamics: the relationship of angle of attack and stall.

# Summary of Swept-Wing Fundamentals

- Flight dynamics: Newton's laws
- Energy states: kinetic, potential, and chemical
- Load factors: longitudinal, lateral, and vertical
- Aerodynamic flight envelope: operating and demonstrated speeds
- Aerodynamics: the relationship of angle of attack and stall

Figure 3-B.55

# Recovery From Airplane Upsets

The first part of the briefing was devoted to the causes of airplane upsets. We had a brief review of how and why large, swept-wing airplanes fly. That information provides the foundation of knowledge necessary for recovering an airplane that has been upset. This section highlights several issues associated with airplane upset recovery and presents basic recommended airplane recovery techniques.

# Airplane Upset Recovery

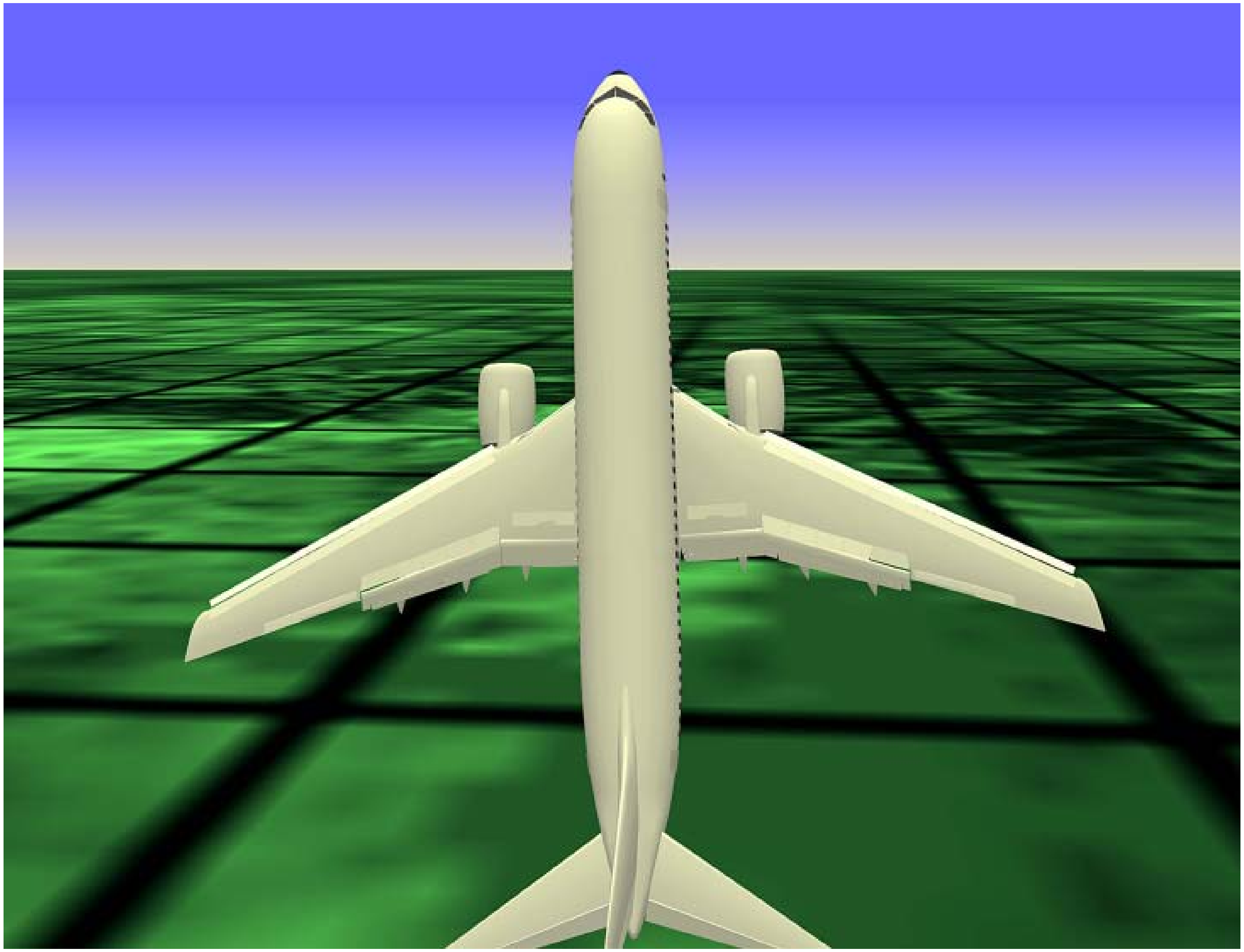


Figure 3-B.56

# Situational Awareness During an Airplane Upset

It is important that the first actions be correct and timely. Guard against letting the recovery from one upset lead to a different upset situation. Troubleshooting the cause of the upset is secondary and can wait. Use the primary flight instruments. Darkness, weather conditions, and the limited view from the cockpit will make it difficult to effectively use the horizon. The attitude direction indicator (ADI) is used as a primary reference.

Situation Analysis Process:

- Communicate with crew members.
- Locate the bank indicator.
- Determine pitch attitude.
- Confirm attitude by reference to other indicators.
- Assess the energy state.

The phrase “recognize and confirm the situation” will be used frequently in discussing recovery techniques. The process outlined above is used to accomplish this.

# Situational Awareness During an Airplane Upset

**"Recognize and confirm the situation" by the following key steps:**

- **Communicate with crew members**
- **Locate the bank indicator**
- **Determine pitch attitude**
- **Confirm attitude by reference to other indicators**
- **Assess the energy state**

Figure 3-B.57

# Miscellaneous Issues Associated With Upset Recovery

Pilots who have experienced an airplane upset have identified several issues associated with recovering from an upset. Observations of pilots in a simulator-training environment have also revealed useful information associated with recovery.

# The Miscellaneous Issues Associated With Upset Recovery Have Been Identified by

- Pilots who have experienced an airplane upset
- Pilot observations in a simulator-training environment

And they are associated with

- The startle factor
- Negative g force
- Full control inputs
- Counter-intuitive factors

Figure 3-B.58

# Startle Factor

Airplane upsets are infrequent; therefore, pilots are usually surprised or startled when an upset occurs. There is a tendency to react before analyzing what is happening or to fixate on one indication and fail to properly diagnose the situation.

# Startle Factor

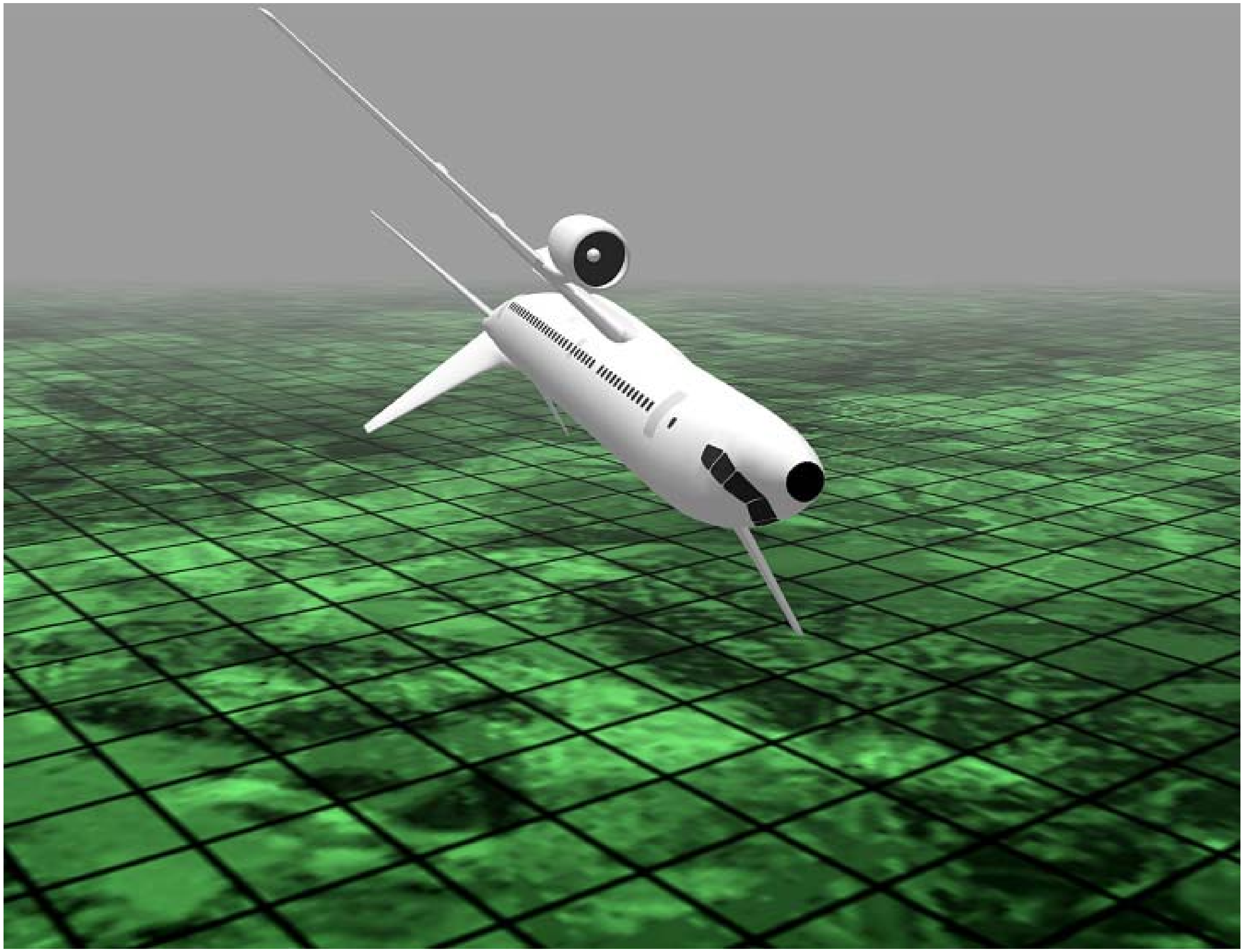


Figure 3-B.59

# Negative G Force

Airline pilots are normally uncomfortable (for the sake of passenger comfort and safety) with aggressively unloading the g forces on a large passenger airplane. This inhibition must be overcome when faced with the necessity to quickly and sometimes aggressively unload the airplane to less than 1 g. Most simulators cannot replicate sustained negative g forces; therefore, the cockpit situation must be envisioned during less than 1-g flight. You may be floating up against the shoulder harness and seat belt. It may be difficult to reach the rudder pedals. Unsecured items may be flying around the cockpit. It should be emphasized that it should not normally be necessary to obtain less than 0 g.

# Negative G Force

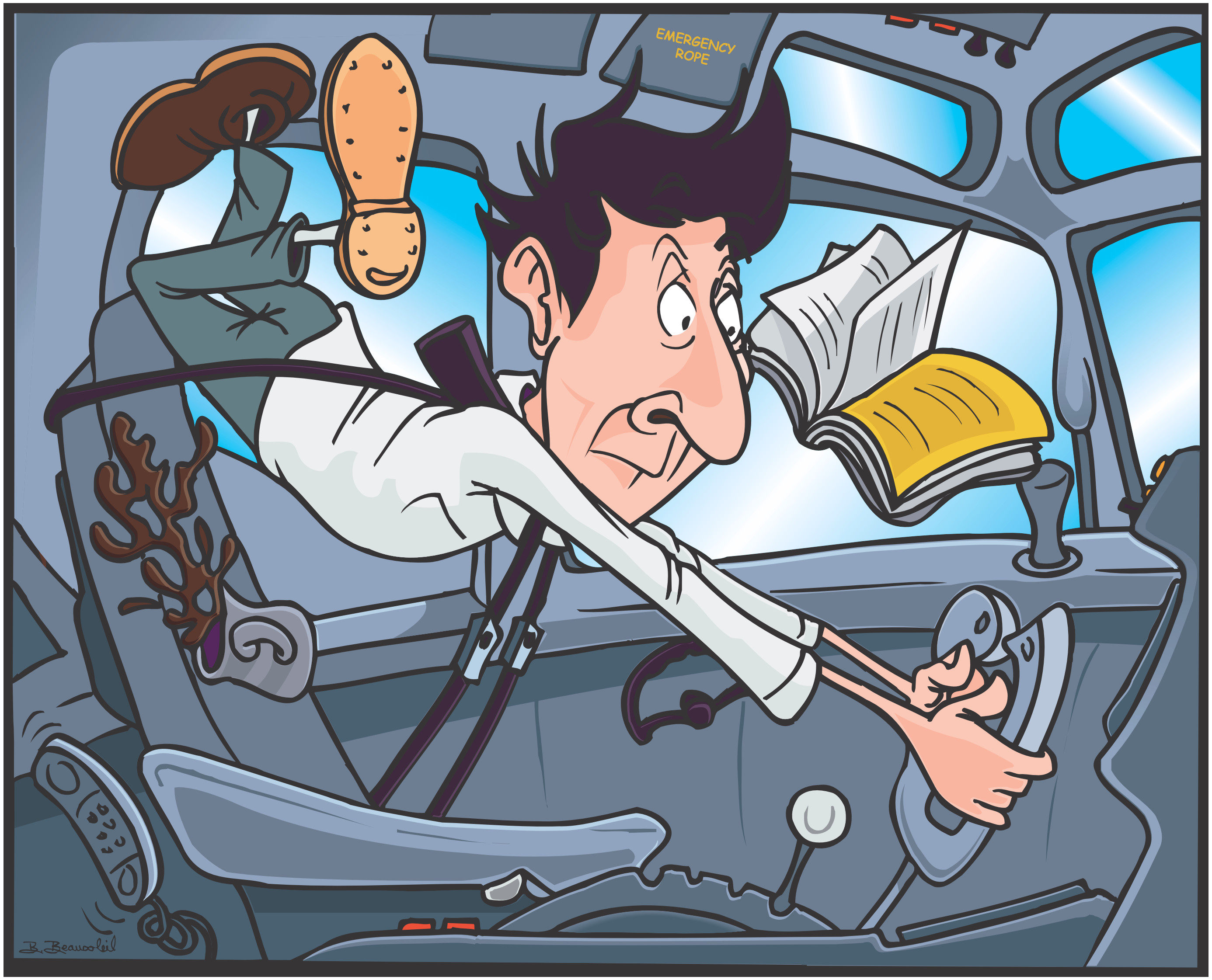



Figure 3-B.60

# Use of Full Control Inputs

Flight control forces become less effective when the airplane is at or near its critical angle of attack or stall. The tendency is for pilots not to use full control authority because they rarely are required to do so. This habit must be overcome when recovering from severe upsets.

# Use of Full Control Inputs

Figure 3-B.61

# Nonintuitive Factors

Pilots are routinely trained to recover from approach to stalls. The recovery routinely requires an increase in thrust and a relatively small reduction in pitch attitude. It may be counter-intuitive to use greater unloading control forces or to reduce thrust when recovering from a high angle of attack, especially at low altitudes. If the airplane is stalled while already in a nosedown attitude, the pilot must still push the nose down (unload) in order to reduce the angle of attack. Altitude cannot be maintained in a stall and should be of secondary importance.

# Nonintuitive Factors

Figure 3-B.62

# Airplane Upset Recovery Techniques

The following airplane upset situations will be discussed:

- Nose high, wings level.
- Nose low, wings level.
- High bank angles.
  - Nose high.
  - Nose low.

At the conclusion, recommended recovery techniques are summarized into two basic airplane upset situations:

- Nose high.
- Nose low.

# Airplane Upset Recovery Techniques Will Include a Review of the Following Airplane Upset Situations:

- Nose high, wings level
- Nose low, wings level
- High bank angles:
  - Nose high
  - Nose low
- And a review of recommended upset recovery techniques based on two basic airplane upset situations:
  - Nose high
  - Nose low

Figure 3-B.63

# Airplane Upset Recovery Techniques (continued)

Recovery techniques assume that the airplane is not stalled. If the airplane is stalled, it is imperative to first recover from the stalled condition before initiating the upset recovery technique. Do not confuse an approach to stall and a full stall. An approach to stall is controlled flight. An airplane that is stalled is out of control but can be recovered. A stall is characterized by any, or a combination of, the following:

- Buffeting, which could be heavy at times.
- A lack of pitch authority.
- A lack of roll control.
- Inability to arrest descent rate.

To recover from a stall, the angle of attack must be reduced below the stalling angle. Apply nosedown pitch control and maintain it until stall recovery. Under certain conditions with underwing-mounted engines, it may be necessary to reduce thrust to prevent the angle of attack from continuing to increase. *Remember, in an upset situation, if the airplane is stalled, it is first necessary to recover from the stall before initiating upset recovery techniques.*

# Airplane Upset Recovery Techniques

- Stall characteristics
  - Buffeting
  - Lack of pitch authority
  - Lack of roll control
  - Inability to arrest descent rate

Figure 3-B.64

# Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing; airspeed decreasing rapidly; ability to maneuver decreasing.

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Apply as much as full nosedown elevator.
- Use appropriate techniques:
  - Roll to obtain a nosedown pitch rate.
  - Reduce thrust (underwing-mounted engines).
- Complete the recovery:
  - Approaching horizon, roll to wings level.
  - Check airspeed and adjust thrust.
  - Establish pitch attitude.

# Nose-High, Wings-Level Recovery Techniques


Figure 3-B.65

# Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing; airspeed decreasing rapidly; ability to maneuver decreasing.

- Apply as much as full nosedown elevator.
- Use nosedown stabilizer trim should stick forces be high.

# Nose-High, Wings-Level Recovery Techniques


Figure 3-B.66

# Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing; airspeed decreasing rapidly; ability to maneuver decreasing.

- Use appropriate techniques:
  - Roll to obtain a nosedown pitch rate.

# Nose-High, Wings-Level Recovery Techniques

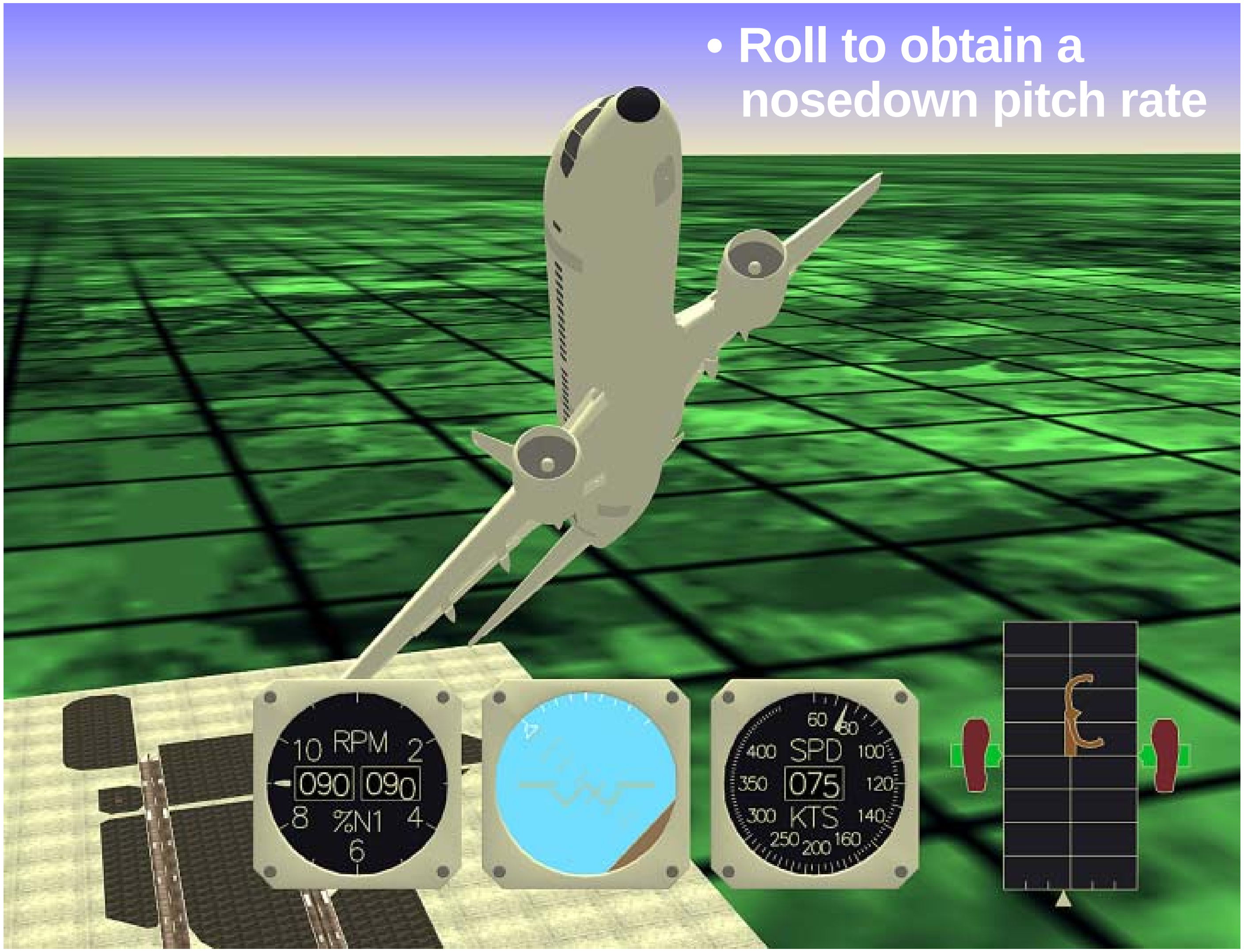



Figure 3-B.67

# Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing; airspeed decreasing rapidly; ability to maneuver decreasing.

- Use appropriate techniques: reduce thrust (underwing-mounted engines).

# Nose-High, Wings-Level Recovery Techniques

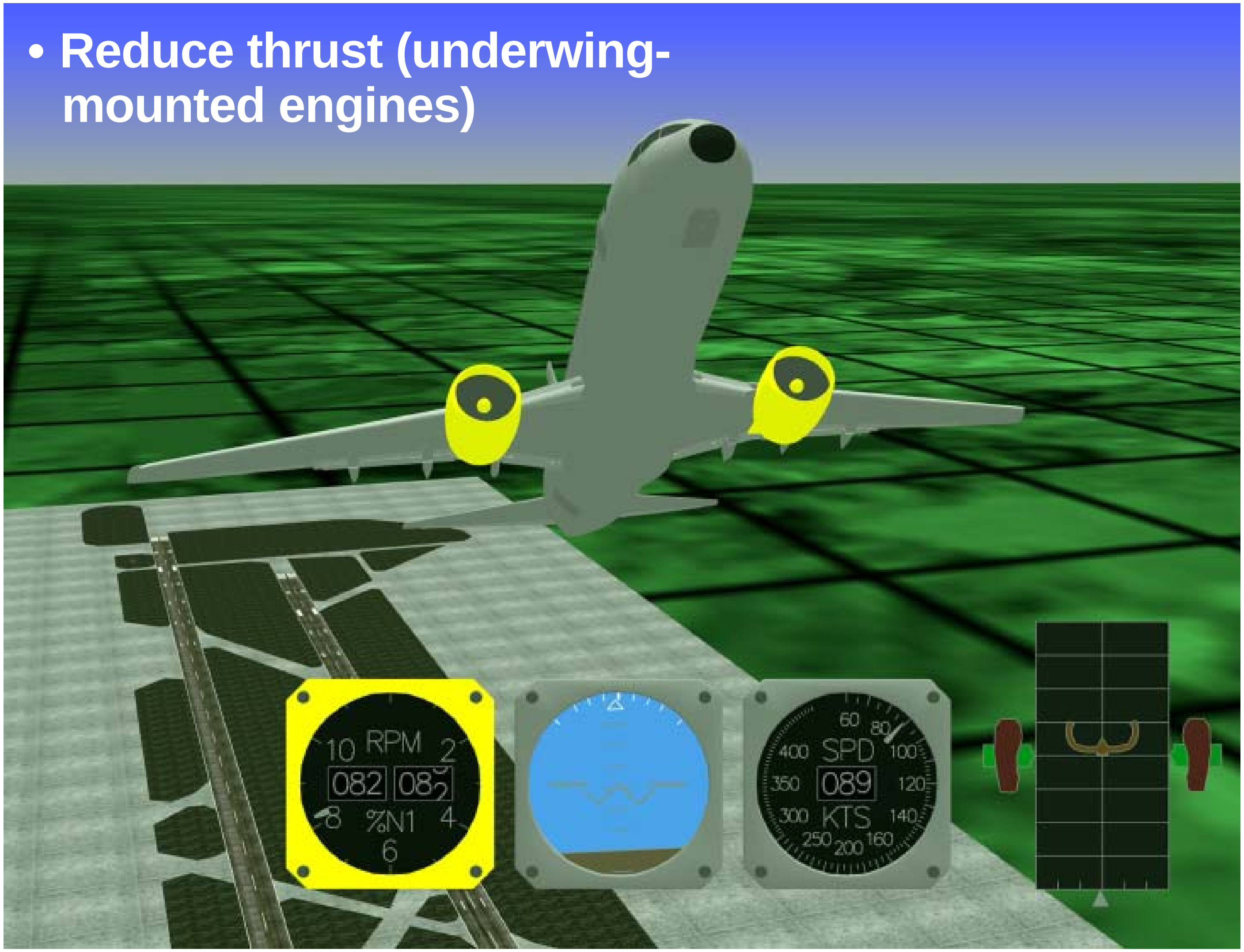



Figure 3-B.68

# Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing; airspeed decreasing rapidly; ability to maneuver decreasing.

- Complete the recovery:
  - – Approaching horizon, roll to wings level.
  - – Check airspeed and adjust thrust.
  - – Establish pitch attitude.

# Nose-High, Wings-Level Recovery Techniques


Figure 3-B.69

# Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Recover from stall, if necessary.
- Recover to level flight.
  - Apply noseup elevator.
  - Apply stabilizer trim, if necessary.
  - Adjust thrust and drag, as necessary.

# Nose-Low, Wings-Level Recovery Techniques

- **Recognize and confirm the situation**

Figure 3-B.70

# Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

- Disengage autopilot and autothrottle.

# Nose-Low, Wings-Level Recovery Techniques


- Disengage autopilot and autothrottle

Figure 3-B.71

# Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

- Recover from stall, if necessary.

# Nose-Low, Wings-Level Recovery Techniques


- **Recover from stall, if necessary**

Figure 3-B.72

# Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

- Recover to level flight:
  - Apply noseup elevator.
  - Apply stabilizer trim, if necessary.

# Nose-Low, Wings-Level Recovery Techniques

Recover to Level Flight


• **Apply noseup elevator**


• **Apply stabilizer trim, if necessary**

Figure 3-B.73

# Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

- Adjust thrust and drag, as necessary.

# Nose-Low, Wings-Level Recovery Techniques


- **Adjust thrust and drag, as necessary**

Figure 3-B.74

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude greater than 25 deg, nose high.

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Reduce the angle of attack (unload).
- Adjust the bank angle to achieve a nosedown pitch rate.
- Complete the recovery:
  - Approaching the horizon, roll to wings level.
  - Check airspeed, adjust thrust.
  - Establish pitch attitude.

# High-Bank-Angle Recovery Techniques


Figure 3-B.75

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude greater than 25 deg, nose high.

- Reduce the angle of attack.
- Adjust the bank angle to achieve a nosedown pitch rate.

# High-Bank-Angle Recovery Techniques

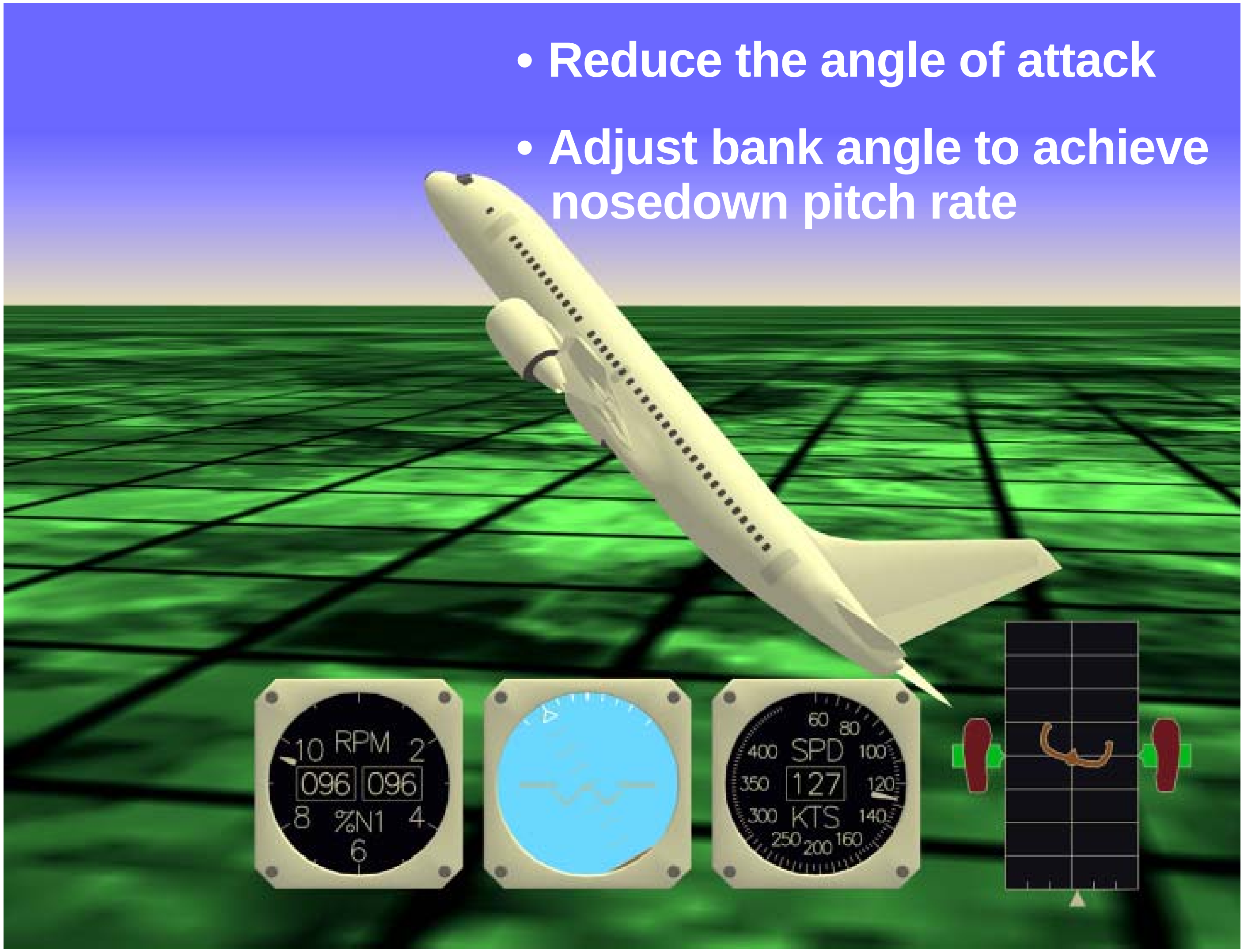



Figure 3-B.76

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude greater than 25 deg, nose high.

- Complete the recovery:
  - Approaching the horizon, roll to wings level.
  - Check airspeed; adjust thrust.
  - Establish pitch attitude.

# High-Bank-Angle Recovery Techniques

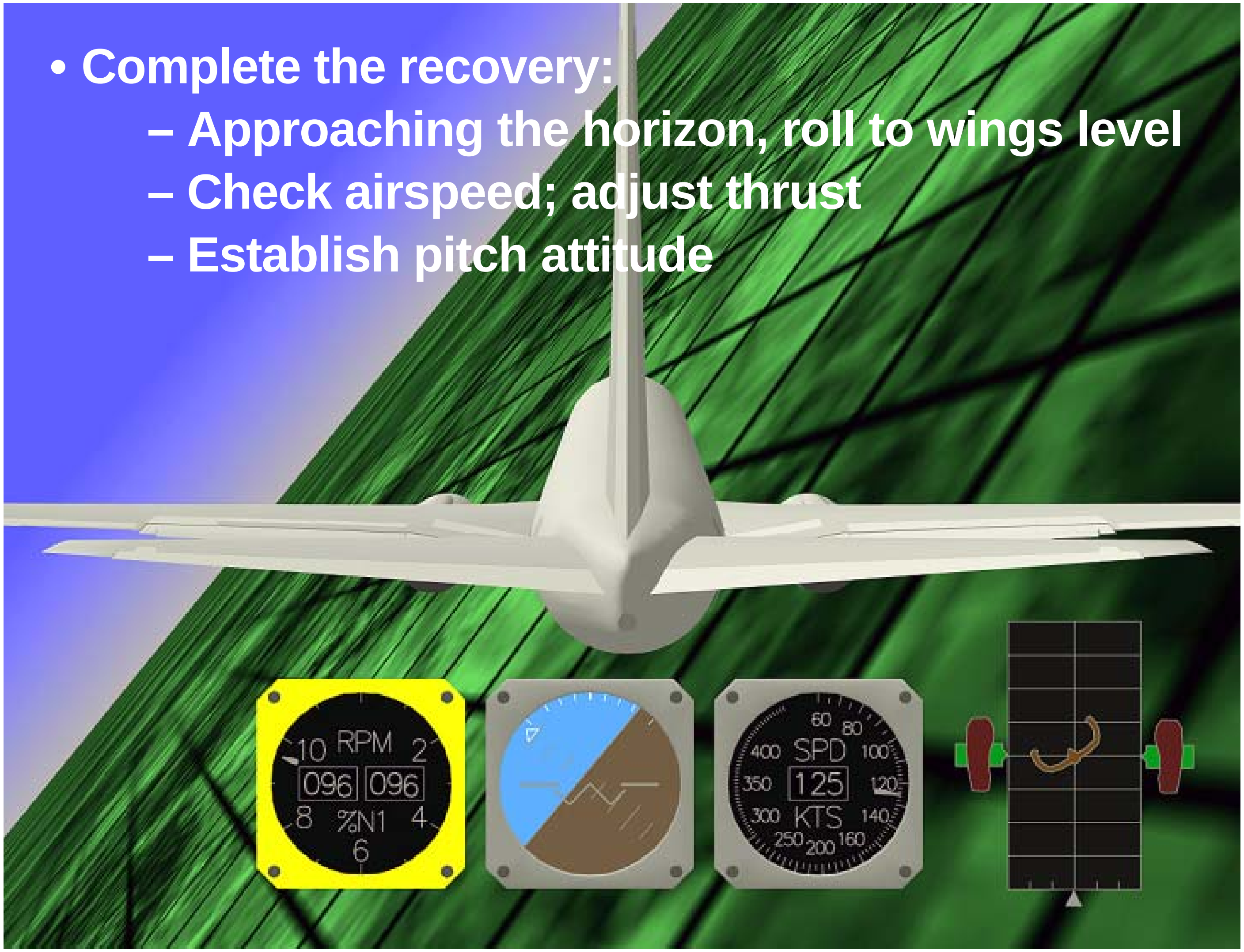



Figure 3-B.77

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude lower than 10 deg; airspeed increasing.

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Reduce the angle of attack, if necessary.
- Simultaneously reduce thrust and roll the shortest direction to wings level.
- Recover to level flight:
  - – Apply noseup elevator.
  - – Apply stabilizer trim, if necessary.
  - – Adjust thrust and drag, as necessary.

# High-Bank-Angle Recovery Techniques

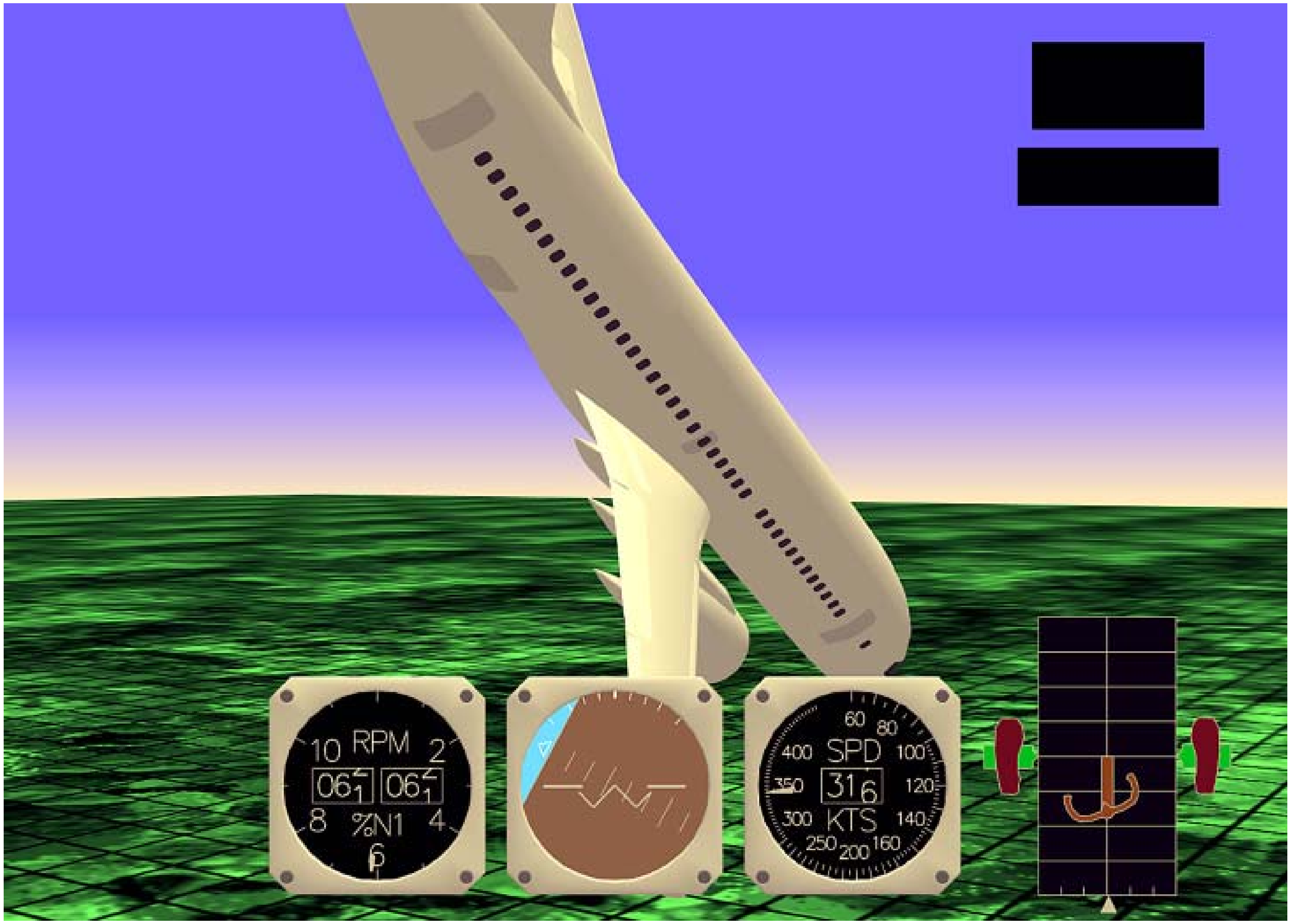

Figure 3-B.78

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude lower than 10 deg; airspeed increasing.

- Reduce the angle of attack, if necessary.

# High-Bank-Angle Recovery Techniques




- **Reduce the angle of attack, if necessary**

Figure 3-B.79

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude lower than 10 deg; airspeed increasing.

- Simultaneously reduce thrust and roll the shortest direction to wings level.

# High-Bank-Angle Recovery Techniques


Figure 3-B.80

# High-Bank-Angle Recovery Techniques

Situation: Bank angle greater than 45 deg; pitch attitude lower than 10 deg; airspeed increasing.

- Recover to level flight:
  - Apply noseup elevator.
  - Apply stabilizer trim, if necessary.
  - Adjust thrust and drag, as necessary.

# High-Bank-Angle Recovery Techniques

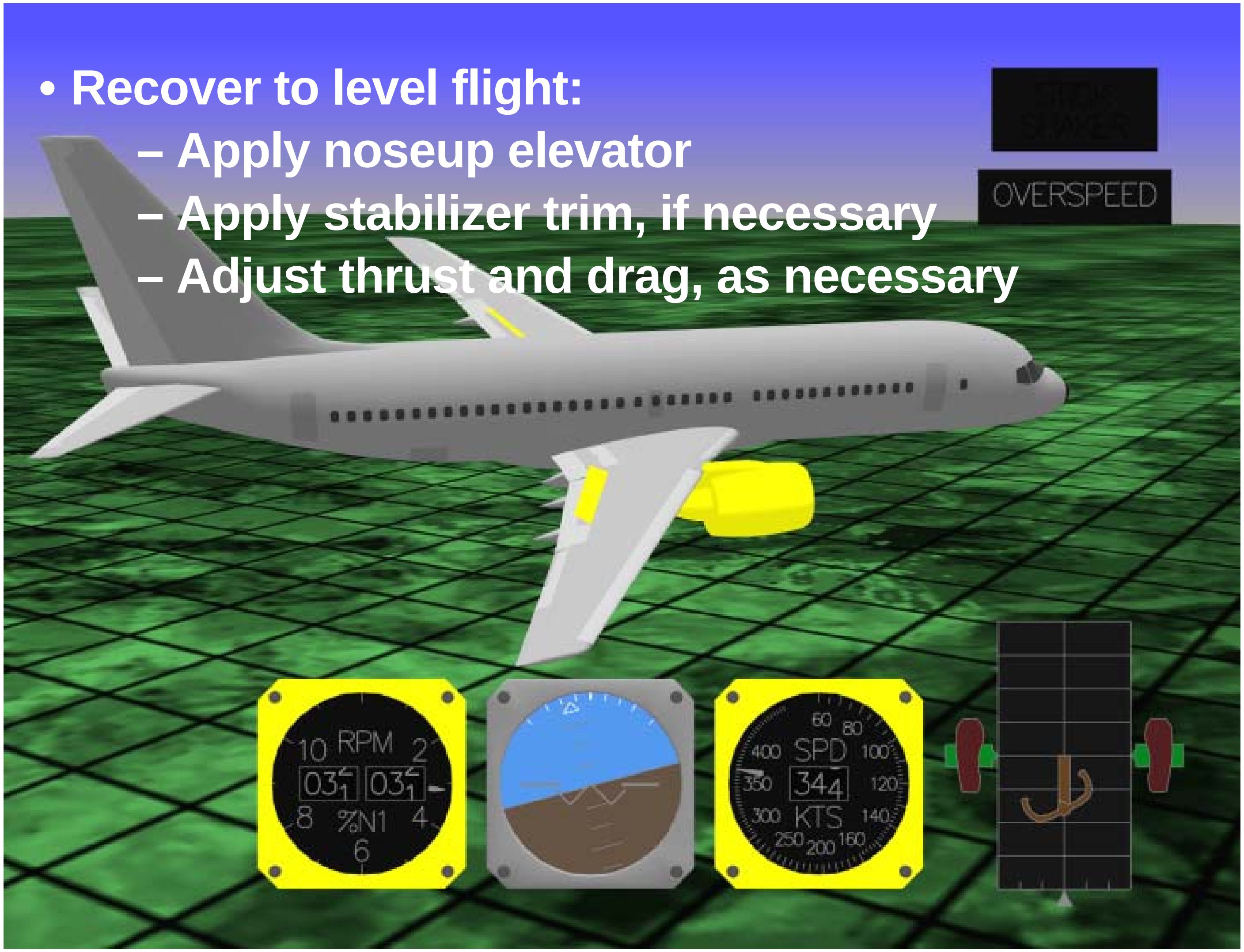



Figure 3-B.81

# Consolidated Summary of Airplane Recovery Techniques

Nose-high recovery:

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Apply as much as full nosedown elevator.
- Use appropriate techniques:
  - – Roll (adjust bank angle) to obtain a nosedown pitch rate.
  - – Reduce thrust (underwing-mounted engines).
- Complete the recovery:
  - – Approaching the horizon, roll to wings level.
  - – Check airspeed, adjust thrust.
  - – Establish pitch attitude.

# Summary of Airplane Recovery Techniques

## Nose-High Recovery

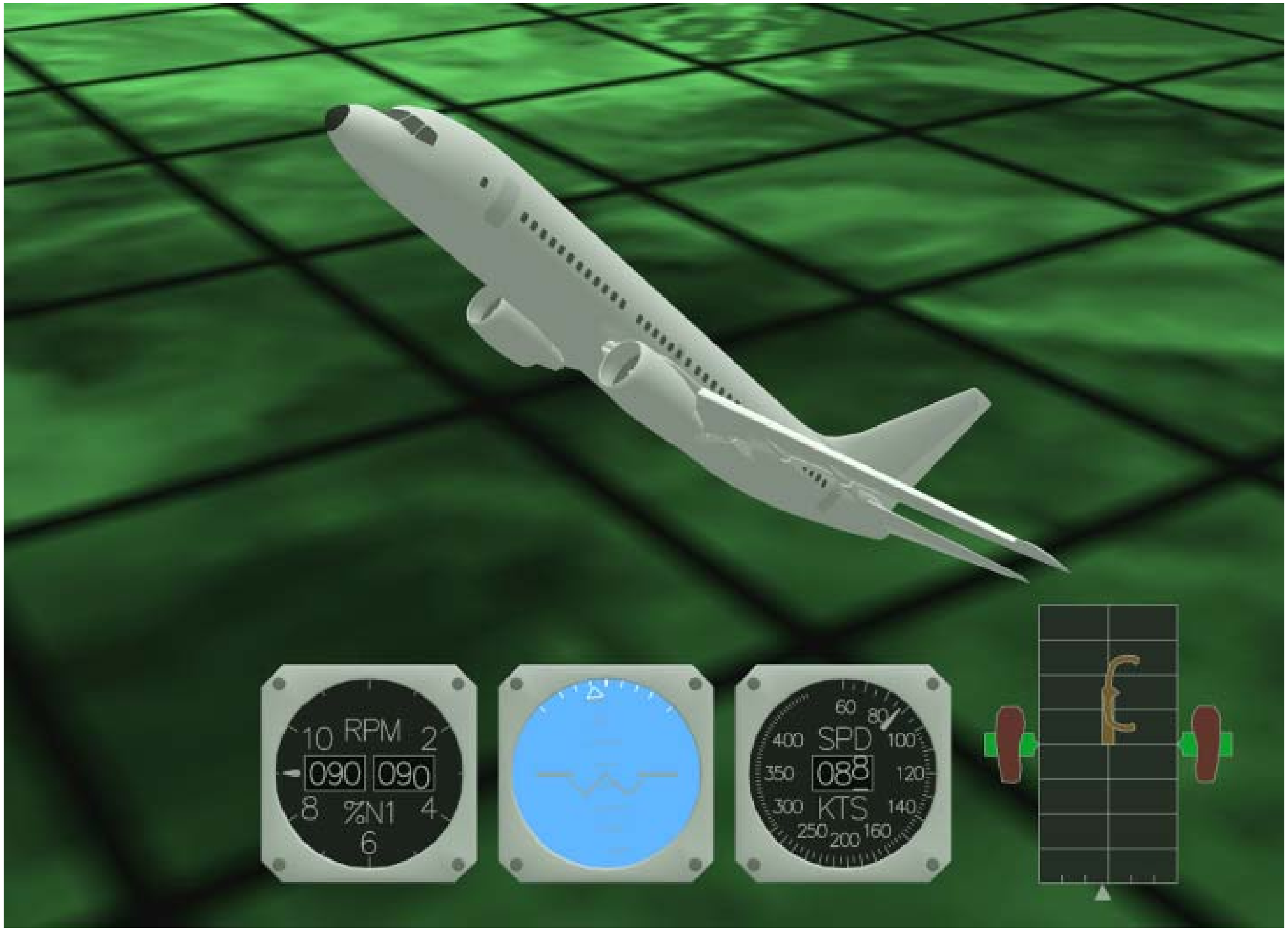



Figure 3-B.82

# Consolidated Summary of Airplane Recovery Techniques

Nose-high recovery:

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Apply as much as full nosedown elevator.

# Summary of Airplane Recovery Techniques

## Nose-High Recovery

- **Recognize and confirm the situation**
- **Disengage autopilot and autothrottle**
- **Apply as much as full nosedown elevator**

Figure 3-B.83

# Consolidated Summary of Airplane Recovery Techniques

Nose-high recovery:

- Use appropriate techniques:
  - – Roll (adjust bank angle) to obtain a nosedown pitch rate.
  - – Reduce thrust (underwing-mounted engines).

# Summary of Airplane Recovery Techniques

## Nose-High Recovery

- **Use appropriate techniques:**
  - **Roll (adjust bank angle) to obtain a nosedown pitch rate**
  - **Reduce thrust (underwing-mounted engines)**

Figure 3-B.84

# Consolidated Summary of Airplane Recovery Techniques

Nose-high recovery:

- Complete the recovery:
  - Approaching the horizon, roll to wings level.
  - Check airspeed; adjust thrust.
  - Establish pitch attitude.

# Summary of Airplane Recovery Techniques

## Nose-High Recovery

- **Complete the recovery:**
  - **Approaching the horizon, roll to wings level**
  - **Check airspeed; adjust thrust**
  - **Establish pitch attitude**

Figure 3-B.85

# Consolidated Summary of Airplane Recovery Techniques

Nose-low recovery:

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Recover from stall, if necessary.
- Roll in the shortest direction to wings level:
  – Bank angle to more than 90 deg; unload and roll.
- Recover to level flight:
  – Apply noseup elevator.
  – Apply stabilizer trim, if necessary.
  – Adjust thrust and drag, as necessary.

# Summary of Airplane Recovery Techniques

## Nose-Low Recovery

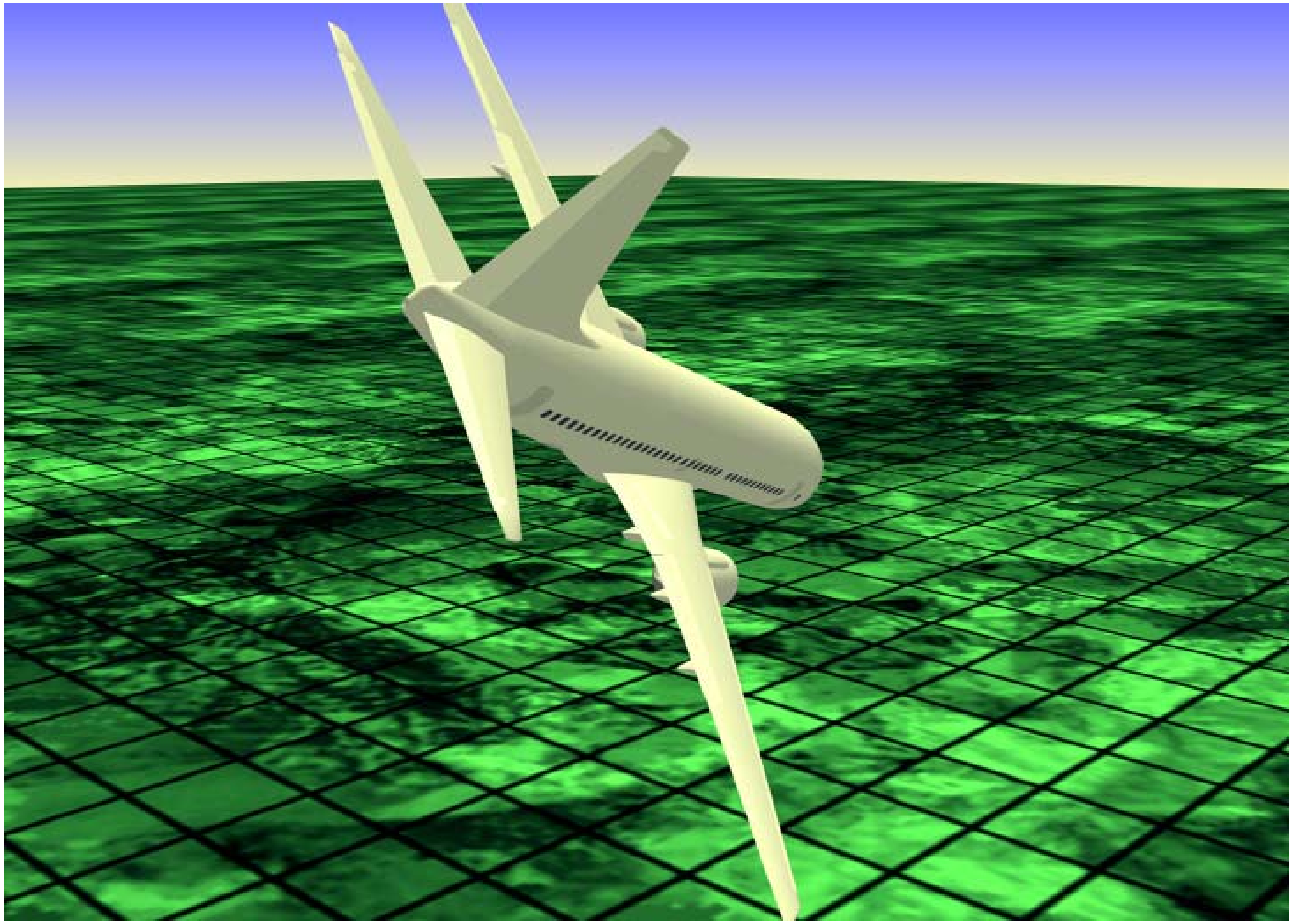


Figure 3-B.86

# Consolidated Summary of Airplane Recovery Techniques

Nose-low recovery:

- Recognize and confirm the situation.
- Disengage autopilot and autothrottle.
- Recover from stall, if necessary.

# Summary of Airplane Recovery Techniques

## Nose-Low Recovery

- **Recognize and confirm the situation**
- **Disengage autopilot and autothrottle**
- **Recover from stall, if necessary**

Figure 3-B.87

# Consolidated Summary of Airplane Recovery Techniques

Nose-low recovery:

- Roll in the shortest direction to wings level:
  - Bank angle to more than 90 deg; unload and roll.

# Summary of Airplane Recovery Techniques

## Nose-Low Recovery

- **Roll in the shortest direction to wings level:**
  - **Bank angle to more than 90 deg; unload and roll**

Figure 3-B.88

# Consolidated Summary of Airplane Recovery Techniques

Nose-low recovery:

- Recover to level flight.
  - Apply noseup elevator.
  - Apply stabilizer trim, if necessary.
  - Adjust thrust and drag, as necessary.

# Summary of Airplane Recovery Techniques

## Nose-Low Recovery

- Recover to level flight
  - Apply noseup elevator
  - Apply stabilizer trim, if necessary
  - Adjust thrust and drag, as necessary

**Return to Main Document**